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APPLICATION AND USE OF THE IRWIN CONSISTOMETER IN ENAMEL SLIP CONTROL*

By L. J. Frost and J. F. Hunt

Abstract

The Irwin consistometer is used to determine the effect of various clays, electrolytes, opacifiers, finenesses of grinding, time of aging, percentage of water addition, and increase of Epsom salts additions and temperatures on ground-coat, cover-coat, and acid-resisting enamel slips. All results are represented in curve form on consistency graphs, which determine the relative yield value and mobility of the respective slips.

I. Introduction

An instrument has recently come into use in laboratory and plant work to determine the consistency of enamel slips. This is a double flow-tube arrangement called the Irwin consistometer.[1]

With this instrument, the yield value and mobility of an enamel slip may be determined by plotting the rate of flow in cubic centimeters per second against the force in dynes of the enamel slip as it emerges from each flow tube or capillary and by drawing a straight line through these two determined points. The slope of this line determines the relative mobility of the slip, and the point at which it crosses the horizontal axis is taken as the yield value in dynes per square centimeter.

The flow in cubic centimeters per second is plotted on the vertical axis and the force in dynes is plotted on the horizontal axis; the flow formula is

$$F = \frac{RhDg}{2L}.$$

Where F = force (dynes/sq. cm.).
R = capillary radius.
h = av. hydrostatic head.
D = specific gravity of slip.
g = gravitation constant.
L = capillary length (cm.).

The present studies show the practical application of this instrument, and although it does not give consistency in absolute values, the values obtained are relative and applicable to testing and control purposes.

II. Method of Procedure

Millings were made in standard laboratory porcelain jar mills to equal finenesses and equal slip specific gravities for each type of enamel, except where the fineness and percentage of water content were used as variables in testing. The enamel slips were screened and stored in glass bottles at an even temperature.

All of the slips in each group were tested within the same period of time, the temperature at the time of test being maintained as constant as possible.

As each enamel was tested, the consistometer was washed twice with the slip to coat the inside of the tube with slip. The consistometer was then filled with enamel, and the time in seconds was taken for the top level of slip to drop from the upper to the lower marking, indicating that a 50-cc. volume had flowed through the capillaries. A watch glass was used to check and introduce the flow of enamel from the consistometer into the graduates.

By plotting the flow in cubic centimeters per second from each capillary against the force in dynes of the enamel as it emerges from the capillary and by drawing the line as determined by these two points, the curves were obtained and comparisons were made.

III. Results and Interpretation

(1) Effect of Various Clays on an Enamel Slip

Figure 1 shows the mill additions and the types of clay used. A comparison of the consistency curves shows that Kentucky ball clay No. 5 (curve 1) gives the lowest yield value and that lump Vallendar (curve 6) gives the highest yield value in this enamel. Cooley clay and Tennessee ball No. 7 (curves 2 and 3) give the lowest and practically equal mobility; Kentucky ball No. 5 (curve 1) has a slightly higher mobility; highest mobility is found in English pipe clay (curve 4), and McKinley, English ball, and lump Vallendar clays are practically equal and next to English pipe clay.

With this type of enamel, these seven clays may be divided into two groups. One group consists of Kentucky ball No. 5, Cooley, and Tennessee ball No. 7; these

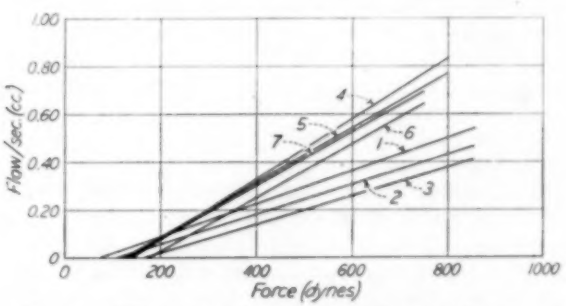

Fig. 1.—Effect of various clays on the set of a cover-coat enamel.

Frit	100
Clay	5
Opacifier	6
Cryolite	1
$NaNO_3$	0.10
Water	40

Types of clay (curves): (*1*) Ky. ball No. 5; (*2*) Cooley; (*3*) Tenn. ball No. 7; (*4*) English pipe; (*5*) McKinley; (*6*) lump Vallendar; (*7*) English ball.

* Presented at the Fortieth Annual Meeting, American Ceramic Society, New Orleans, La., March 29, 1938 (Enamel Division). Revised copy received April 5, 1939.

[1] J. T. Irwin and R. E. Bevis, "Modification of the Bingham Plastometer," *Jour. Amer. Ceram. Soc.*, **21** [2] 66–72 (1938).

clays are suitable for dry-spraying slips because of the low mobility they impart. Tennessee ball No. 7 should be the best for double-spraying and acid-resisting dust-coat or heavy one-coat applications because it gives a high yield value, which tends to offset blending with a wet undercoat or sagging of the heavy coat.

The other group consists of English pipe, McKinley, English ball, and lump Vallendar clays, which are suitable for general use because of their relatively high mobility and yield values. Lump Vallendar should be the best of these clays for heavy dipping application because it produces high yield value as well as high mobility.

(2) Effect of Various Electrolytes on Consistency of a Draining Ground Coat

In Fig. 2, only one consistency curve has a positive yield value. The remaining four curves cross the horizontal axis at a value of less than zero; these four slips had poor set and were too runny to get a proper determination with this instrument and its capillary diameters. Capillaries of smaller diameters undoubtedly would have given curves with a positive yield value. The curves shown, however, are comparative and point out the fact that borax (curve 2) gives the best set and draining properties because of the high yield value it imparts. This fact was borne out by actual dipping tests which showed the borax enamel to drain to a smooth even coating on the pickled panel; the other slips were found to break and orange peel on draining. These draining tests showed the sodium nitrite slip (curve 3) to be next to the borax slip, thus checking the curves. All five slips had practically the same mobility and draining time, but only the high yield value left a coating heavy enough on the pickled panel.

(3) Effect of Various Electrolytes on Consistency of a Cover-Coat Enamel

The slips containing no electrolyte (Fig. 3, curve 5) and sodium carbonate (curve 3) have unsatisfactory yield values, sodium carbonate being the poorer. Sodium fluoride (curve 4), sodium nitrite (curve 2), and magnesium carbonate (curve 1) increase the yield value of this enamel. Magnesium carbonate is the best of the three for some spraying applications because of its high yield value and low mobility. Sodium fluoride and sodium nitrite would be better for dipping purposes because of the higher mobility they impart and their good yield value.

(4) Effect of Various Electrolytes on Mobility and Yield Value of an Acid-Resisting Enamel

Figure 4 shows a situation similar to that shown in Fig. 2 in the ground-coat electrolyte studies, *i.e.*, all of the millings apparently have a negative yield value. These are comparative, however, and the electrolytes that give the lowest mobility to the enamel slip are calcium chloride and ammonium alum (curves 5 and 6). Calcium chloride is the better of the two because of its higher yield value. Ammonium carbonate is a good setting-up agent for this enamel because it gives the highest yield value of any of the electrolytes tested, although it has a higher mobility than either calcium chloride or ammonium alum. Sodium aluminate is not very satisfactory for this enamel because of the relatively low yield value and high mobility it imparts. The potassium carbonate and "no electrolyte" millings are unsatisfactory.

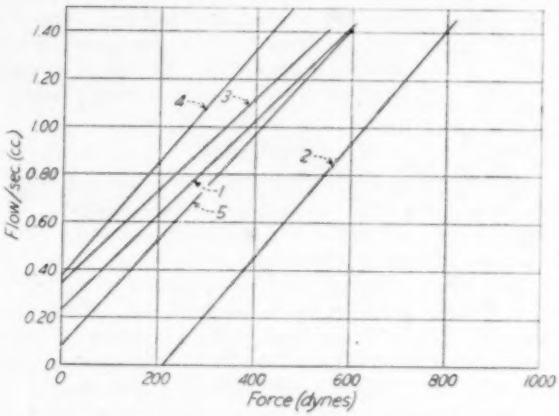

FIG. 2.—Effect of various electrolytes on the set of a draining ground coat.

Frit	100	*Specific gravity:* after milling, 1.74; after thinning, 1.68; *age*, 20 hr. *Consistency curves:* (*4*) K_2CO_3 set; (*3*) Na_2CO_3 set; (*1*) $MgCO_3$ (alone) set; (*5*) $NaNO_2$ set; (*2*) borax set.
Clay	7	
$MgCO_3$	1/8	
Electrolyte	1/2	
Water	45	

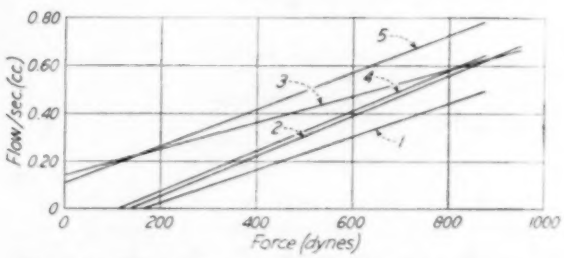

FIG. 3.—Effect of various electrolytes on the set of cover-coat enamel.

Frit	100	*Specific gravity:* 1.83; *age*, 19 hr. *Curves:* (*5*) no electrolyte; (*3*) Na_2CO_3 set; (*4*) NaF set; (*2*) $NaNO_2$ set; (*1*) $MgCO_3$ set.
Clay	6	
Opacifier	6	
Electrolyte	1/4	
Water	40	

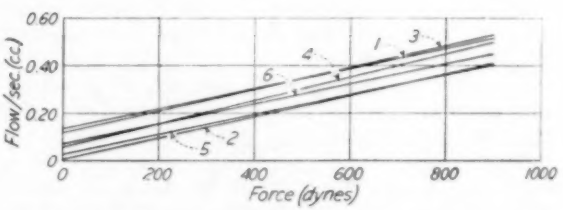

FIG. 4.—Effect of various electrolytes on the set of an acid-resisting enamel.

Frit	100	*Specific gravity:* 1.84; *age*, 18 hr. *Curves:* (*1*) no electrolyte; (*2*) $(NH_4)_2CO_3$; (*3*) K_2CO_3; (*4*) sodium aluminate; (*5*) $CaCl_2$; (*6*) ammonium alum.
Clay	7	
Opacifier	6	
Electrolyte	1/4	
Water	40	

(5) Effect of Various Opacifiers on Consistency of Cover-Coat and Acid-Resisting Enamels

The cover-coat enamel consistency curves (Fig. 5) are shown in solid lines. With the no-opacifier curve (1) as the basis of comparison, Hy-Opax (curve 3) is shown to lower the set of this enamel because it decreases the yield value and increases the mobility. Tin oxide (curve 2) does not change the set of this enamel very much because it increases slightly both the yield value and mobility. Tre-Opax and Opax (curves 4 and 5) noticeably increase the set of this enamel and lower the mobility considerably even though they have about the same yield value as tin oxide; Tre-Opax is the better of the two.

FIG. 5.—Effect of various opacifiers on the set of a cover coat and an acid-resisting enamel.

	Cover coat (solid lines)	Acid resisting (broken lines)
Frit	100	100
Clay	7	7
Opacifier	4	6
$MgCO_3$	1/8	
K_2CO_3		1/8
Water	40	38
Specific gravity	1.88	1.98
Age (hr.)	60	40

Curves: (*1*) no opacifier; (*2*) tin oxide; (*3*) Hy-Opax; (*4*) Tre-Opax; (*5*) Opax.

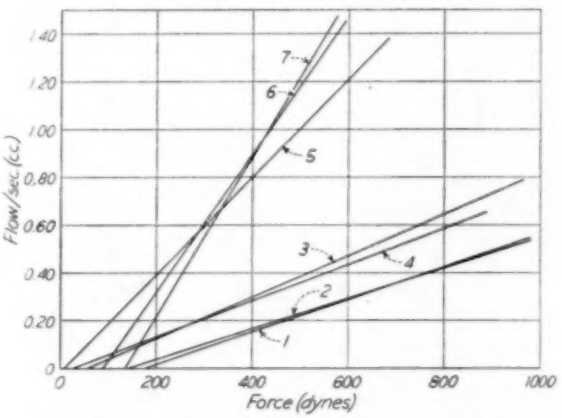

FIG. 6.—Effect of fineness of grinding on spraying cover coat and draining ground coat.

	Ground coat	Cover coat
Frit	100	100
Clay	7	6
Borax	1/2	
Water	55	40
Opacifier		6
$MgCO_3$		1/4
Age (days)	2	1 1/2

Ground-coat curves: (*5*) 0.0 g.; (*6*) 8.0 g.; (*7*) 12.0 g.; *cover-coat curves:* (*3*) 8.5 g.; (*4*) 12.5 g.; (*2*) 4.0 g.; (*1*) 0.0 g.

The acid-resisting enamel consistency curves (Fig. 5) are shown in broken lines. Opax (curve 5) is by far the best for setting up this enamel because of the high yield value and low mobility it imparts. Tin oxide and Tre-Opax (curves 2 and 4) give approximately the same yield value, but Tre-Opax is better because of its lower mobility. Hy-Opax (curve 3) shows the lowest yield value of all. Opax gives a set to the acid-resisting enamel similar to that given to the cover-coat enamel by the opacifiers.

(6) Effect of Fineness of Grinding on a Spraying Cover Coat and a Draining Ground Coat

The ground coat, shown in Fig. 6, is milled finer, but it has been kept within the present commercial limits. The yield value of the slip as well as its mobility decreases. Inasmuch as the yield value is a limiting factor, it is inadvisable to mill finer than 8 grams for otherwise the pickup of ground coat on the pickled panel would be too light (much finer grinding probably would reverse this finding). Milling coarser than 12 grams would tend to give this ground coat a higher mobility and would provide a suitable dipping slip.

A comparison of the consistency curves for the cover coat (Fig. 6) shows that its yield value increases the finer it is ground, and from the range of 12.5 to 0.0 gram there is comparatively little change in mobility. There are two groupings of this cover-coat milling, one 0 to 4 grams and the other 8.5 to 12.5 grams. In both groups, the mobility tends to increase as the yield value increases.

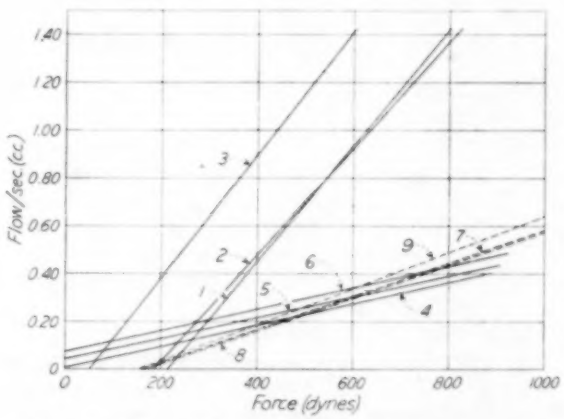

FIG. 7.—Effect of aging on draining ground coat, spraying cover coat, and acid-resisting enamel.

	Ground coat	Cover coat	Acid-resisting
Frit	100	100	100
Clay	7	6	7
Opacifier		6	6
Borax	1/2		
$MgCO_3$	1/8	1/4	
$(NH_4)_2CO_3$			1/4
Water	45	40	40
Specific gravity	1.680	1.832	1.850

Cover-coat curves (age): (*7*) 18 hr.; (*8*) 4 1/2 days; (*9*) 8 days; *ground-coat curves (age):* (*3*) 8 days; (*2*) 4 1/2 days; (*1*) 20 hr.; *acid-resisting curves (age):* (*6*) 8 days; (*5*) 4 1/2 days; (*4*) 18 hr.

(7) Effect of Aging on a Draining Ground Coat, a Spraying Cover Coat, and an Acid-Resisting Enamel

There was practically no change in the mobility of this enamel on aging (see Fig. 7). As the slip became older, however, the yield value decreased, allowing less pickup per square foot of the ground coat. There was a much greater loss in yield value between aging $4^1/_2$ and 8 days than between 1 and $4^1/_2$ days. This ground coat, therefore, should have good dipping properties up to $4^1/_2$ days without any adjustments or additions.

In cover-coat enamel, there has been little change in mobility on aging and the decrease in yield value has been very slight. Upon aging, this enamel slip has good set characteristics.

In the acid-resisting enamel, there is no noticeable change in mobility upon aging, but there is quite a decrease in yield value. The decrease in yield value from 18 hours to $4^1/_2$ days is about equivalent to the decrease from $4^1/_2$ days to 8 days. These results show how this enamel, like many other acid-resisting enamel slips, changes rapidly upon aging.

(8) Effect of Percentage Milled in Water Addition on Set of a Ground-Coat and Cover-Coat Enamel

The consistometer curves in Fig. 8 (solid lines) show that as the percentage water addition increases the set of the ground-coat enamel is lowered by a decrease in the yield value and an increase in the mobility.

The curves for the cover-coat enamel (broken lines) show the results to be the same as for the ground coat.

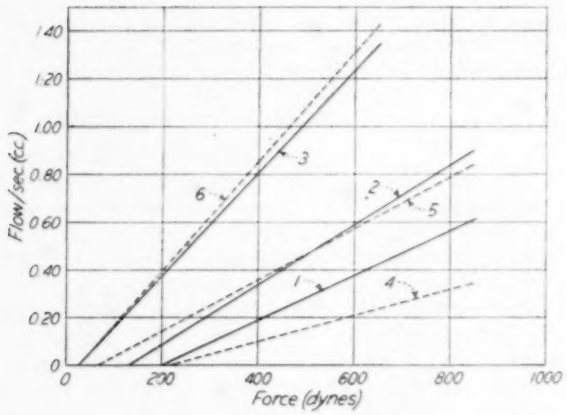

FIG. 8.—Effect of percentage milled in water addition on set of ground-coat and cover-coat enamel.

	Ground coat (solid lines)	Cover coat (broken lines)
Frit	100	100
Clay	7	6
Borax	$^1/_2$	
Water	45, 50, 55	40, 45, 50
Opacifier		6
$MgCO_3$		$^1/_4$
Age (days)	3	3

Curves: (*6*) 50% water, sp. gr., 1.742; (*3*) 55% water, sp. gr., 1.662; (*5*) 45% water, sp. gr., 1.772; (*2*) 50% water, sp. gr., 1.698; (*1*) 45% water, sp. gr., 1.720; (*4*) 40% water, sp. gr., 1.824.

(9) Effect of Epsom Salts Additions to One-Coat Blue Dipping Enamel

The consistency determination is shown in Fig. 9 (curve 1). To approximately one quart of this slip, 1 cc. of Epsom salts solution was added, thoroughly stirred in, and another consistency determination was made (curve 2); this procedure was repeated until five curves were obtained. After each Epsom salts addition, the dipping properties of the slip were determined by tong-dipping a small pudding pan.

Curves (1), (2), and (3) are parallel and have the same mobility; the salts additions have just increased

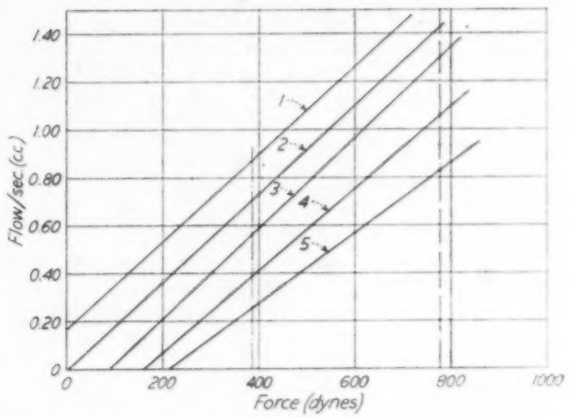

FIG. 9.—Effect of Epsom salts additions to one-coat dipping blue enamel. Frit 100, clay 7, $MgCO_3$ $^1/_4$, $NaNO_2$ $^1/_{10}$, and water 45.

Specific gravity: 1.708; *age,* 46 hr.; $MgSO_4$ solution added: *curve* (*1*) none; (*2*) 1 cc.; (*3*) 2 cc.; (*4*) 3 cc.; (*5*) 4 cc.

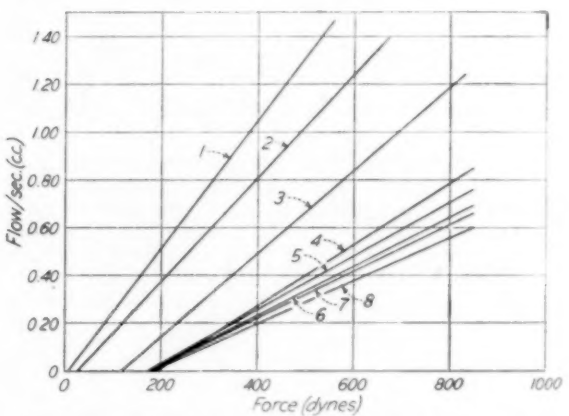

FIG. 10.—Effect of temperature variations on set of draining ground coat and spraying cover coat.

	Ground coat	Cover coat
Frit	100	100
Clay	7	7
Borax	$^1/_2$	
Water	55	40
Specific gravity	1.662	1.80
Age	3 days	45 hr.

Ground-coat curves: (*1*) 97°F; (*2*) 81°F; (*3*) 57°F; *cover-coat curves:* (*4*) 83°F; (*5*) 74°F; (*6*) 65°F; (*7*) 57°F; (*8*) 50°F.

the yield value; curve (4) shows that the third salts addition has increased the yield value and decreased the mobility; curve (5) shows that the fourth salts addition has further increased the yield value and decreased the mobility.

The best dipping properties were obtained at curve (4). Curves (1), (2), and (3) gave too light an application, and the enamel shook off too easily. Curve (5) gave too heavy an application, and the enamel could not be applied smoothly because it was too stiff or the mobility was too low.

It is suggested that the first noticeable decrease in mobility (shown by the consistency curves) might be taken as the end point of salts additions in production control. There is the combination at this point of the highest yield value and highest mobility obtainable; together, these will give a heavy application with smooth draining.

(10) Effect of Temperature Variations on Set of a Draining Ground Coat and a Spraying Cover Coat

Curves (1), (2), and (3) in Fig. 10 for the ground coat show that an increase in temperature decreases the yield value of this slip and at the same time increases the mobility, causing the ground coat to lose set with increase of temperature.

Curves (4) to (8) for the cover coat show that an increase in the temperature of this slip has little or no bearing on the yield value but merely increases the mobility of the slip and leaves the yield value constant.

IV. Summary

The influence of the yield point and mobility of an enamel slip, which may result from the many variables encountered or introduced in enameling practice, may be shown graphically. The Irwin consistometer has proved to be a valuable piece of equipment in securing accurate comparisons of various materials and procedures.

When the instrument is applied to test enamel slip control, it is possible to check every constituent that goes into the mill addition for its reaction on yield value and mobility of the resulting slip.

This work has shown the varied reactions of the different clays and electrolytes on the different types of enamel slips. An opacifier addition to an enamel is beneficial to the consistency and workability of the slip, but some types of opacifiers are considerably better than others for this purpose. The variables of fineness of grinding, aging, temperature, and water content of enamels have been discussed, and the limits of these variables before exceeding the good workability limit of an enamel are shown.

Because these results were determined from enamels in everyday use, they do not necessarily apply to the particular enamels and slips used in every plant. The authors hope that these studies will stimulate interest in this type of consistency determination to the point where each enamel plant will set up standards for control and test purposes for its particular enamel slips.

The Titanium Alloy Manufacturing Company
Niagara Falls, New York

STRESSES IN PORCELAIN GLAZES*

By A. L. Johnson

Abstract

The stresses developed by five glazes in the field of cone 9 porcelain glazes were determined by the tuning fork method of Blakely. A reaction between the body and glaze at the interface causes a development of stress above the softening point of the glaze. The mat glaze studied showed no crazing even though it was extremely high in tension, whereas a semimat and clear glaze, lower in tension, showed craze marks.

I. Introduction

In the selection of the proper glaze, few means exist outside the trial and error method. The usual crazing tests are only qualitative. Blakely[1] has given a convenient and practical method for the measurement of stress in a cooling glaze.

II. Procedure

A porcelain body was made for this study as follows: English ball clay 25, English china clay 21, feldspar 32, and flint 22%.

A casting slip was prepared by ball milling the aged body with sufficient water to obtain a specific gravity value of about 1.80 to 1.82 (30 to 30½ ounces per pint) for the slip. To obtain the proper fluidity, 0.2% deflocculent, based on the weight of the dried body, was introduced. The "tuning-fork" specimen was prepared by casting bars and cementing them to a short piece with slip as described by Blakely.[1]

The specimens were biscuited to 550°C to facilitate handling, after which the glaze was sprayed on and the piece was fired to cone 9 down (1235°C). The rate of heat increase was about 40°C per hour, and the soaking period at 1235°C was one hour, thereby approximating industrial tunnel firing conditions.

The field of porcelain glazes as worked out by Stull and Howat[2] was used as a guide in the selection of five compositions within the area of mature glazes.

* Presented at the Forty-First Annual Meeting, American Ceramic Society, Chicago, Ill., April 20, 1939 (Symposium on Glaze Properties). Received April 14, 1939.

[1] A. M. Blakely, "Life History of a Glaze: II, Measurement of Stress in a Cooling Glaze," *Jour. Amer. Ceram. Soc.*, **21** [7] 243–51 (1938).

Composition A lies in the crazing area as shown in Fig. 1 (redrawn from the work by Stull and Howat[2]). Composition C lies in the area for mat glazes and the remaining compositions (B, D, and E) are in the field for bright glazes.

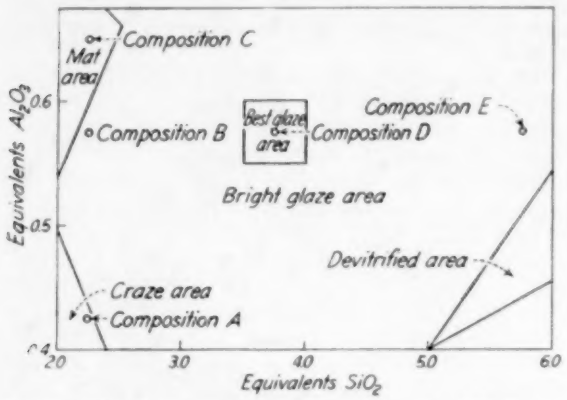

FIG. 1.—The field as redrawn from the work of Stull and Howat showing the compositions given in Table I.

The molecular compositions of the glazes are given in Table I.

TABLE I

Composition	Al_2O_3	SiO_2
A	0.425	2.25
B	0.575	2.25
C	0.650	2.25
D	0.575	3.75
E	0.575	5.75

0.3 K_2O + 0.7 CaO was used throughout.

III. Results

Examination of the specimen after firing showed that the glaze appearance in each case checked the results of Stull and Howat.[2] Composition A was a bright glaze showing crazing; composition B, a semimat with a slight crazing; composition C, a good mat glaze with no crazing apparent; and compositions D and E, good clear glazes with bright texture and no crazing.

The results of the stress determination on each sample show that compositions A, B, and C are in tension and that D and E are in compression. Glaze A, which is a clear glaze with bad craze marks, is in tension to the extent of only 4 kilograms per square millimeter, whereas glaze B, which is a semimat with few craze marks, is in tension with a value of almost 12.5 kg. per sq. mm. The mat glaze, composition C, which shows no crazing, is in tension to the same extent as composition B. These data are shown clearly in Fig. 2.

The determination of stress in the glazed specimens was made by cooling from a temperature of 1135°C, which is 100° below the firing temperature of the pieces (Fig. 2).

Blakely[1] states that zero stress is obtained when the glaze is fluid, that is, at the softening point. The softening point of composition D is 830°C (Fig. 3). The softening temperature for the other points was not determined, but they undoubtedly exist near 830°C. Any stress development between the body and glaze of the original composition, therefore, should commence near this temperature. Owing to the greater reaction between body and glaze in the one-fire system,[3] a stress development, probably attributable to this reaction, would be revealed. For this reason the stresses were developed above 830°C.

IV. Stress Calculations

Blakely's[1] formula for glaze stress in a straight piece is as follows:

$$S'ga = \frac{Sga - \frac{Eg}{E} Sa}{1 + \left(\frac{Eg}{E} \cdot \frac{b-a}{a}\right)}. \qquad (1)$$

When Sga = glaze stress in a curved piece.

Or
$$Sga = \frac{-Ea^3}{6bl^2(b-a)}\, d, \qquad (2)$$

and Sa = body stress in a curved piece.

Or
$$Sa = \frac{2Ea}{3l^2}\, d, \qquad (3)$$

When
Eg = glaze modulus of elasticity.
E = body modulus of elasticity.
a = body thickness (mm.).
b = body and glaze thickness (mm.).
d = deflection (mm.).
l = glazed specimen length (mm.).

The solution of equations (1), (2), and (3) is accomplished by a substitution of the values listed in Table II. The value of Eg (modulus of elasticity of the glaze) was calculated from equations given by Hall[4] for each particular composition. The value of E was determined on a bar of the unglazed body.

TABLE II

Glaze specimen	a (mm.)	b (mm.)	l (mm.)	E (kg./mm.²)	Eg (kg./mm.²)
A	4.16	4.35	149	6500	8070
B	4.10	4.26	146	6500	8060
C	4.21	4.40	145	6500	8130
D	4.29	4.43	147	6500	7530
E	4.21	4.37	144	6500	7130

Table III gives the results of these calculations, and, upon inserting the value of d for any given temperature, the glaze stress in kilograms per square millimeter is obtained.

TABLE III

Glaze specimen	Sga	Sa	$S'ga$
A	$-4.25d$	$+0.815d$	$-5.0d$
B	$-5.12d$	$+0.83d$	$-5.86d$
C	$-4.58d$	$+0.87d$	$-5.35d$
D	$-6.33d$	$+0.86d$	$-7.10d$
E	$-5.53d$	$+0.88d$	$-6.22d$

[2] R. T. Stull and W. L. Howat, "Deformation Temperatures of Some Porcelain Glazes," *Trans. Amer. Ceram. Soc.*, **16**, 455–60 (1914).

[3] Even though the specimens were biscuited to 550°C before glazing, this treatment could not be classed in the two-fire category.

[4] F. P. Hall, "Influence of Chemical Composition on Physical Properties of Glazes," *Jour. Amer. Ceram. Soc.*, **13** [3] 182–99 (1930).

V. Discussion

The correct proportion of alumina and silica to be used in a glaze should be determined in order to obtain the best results for any given set of conditions. Because of the introductory nature of this research, any attempt to set rigid rules governing this factor without first analyzing the entire field would be misleading. The general statements given here, however, apply to the points already studied.

Stull and Howat[2] show that the most fusible point in the field studied corresponds to the group eutectic, *viz.*, 0.6 equivalent alumina and 4.0 equivalents silica, or a 1 to 6.6 ratio of alumina to silica. Composition D selected from this area of "best glazes" has a 1 to 6.5 alumina to-silica-ratio.

A study of the curves in Fig. 2 shows that this glaze is in greater compression than any other composition studied. Glaze C is the highest in tension, with an alumina-to-silica ratio of 1 to 3.5.

Concerning the compositions studied, it seems that with the smallest ratio of alumina to silica, 1 to 3.5, the resulting glaze has the highest tension (glaze C). The tension decreases in the specimens as the amount of silica is increased until the most fusible glaze is obtained (glaze D). The glaze, at this point, will be in greatest compression. As the ratio is increased by additions of silica, the glaze slowly moves toward stress in tension (glaze E in Fig. 2).

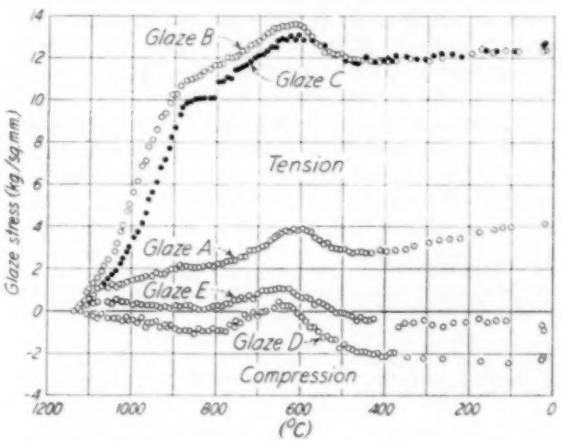

FIG. 2.—Stress curves on body and glazes matured at cone 9.

It is well to remember that a glaze in tension has a tendency to craze, but one in compression will not exhibit this phenomena. A high-alumina glaze, however, will resist crazing (even if it is in great tension) by virtue of its crystalline structure. The formation of the crystalline bond would tend to increase the elastic properties of the structure, and this may be the explanation of the absence of craze marks in such a specimen (glaze C). Schurecht and Pole[5] stated that "in general, it was found that mat glazes, due to their lower thermal expansions, are in stronger compression on ceramic bodies than bright glazes and hence are more resistant to crazing." This generality does not seem to apply in this particular case in which mat glaze C had a value of stress in tension higher than that for any other composition studied.

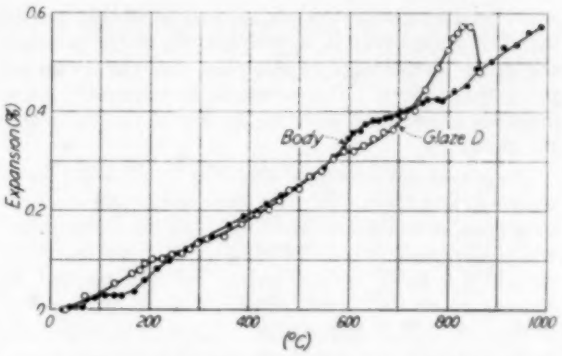

FIG. 3.—Expansion curves on unglazed body and glaze D.

Certain features of good glaze fit should be defined before the curves are discussed in detail. In the theoretical case, no stress between body and glaze will be developed if the expansion of both is the same over the range of temperature from the softening point of the glaze to room temperature. A simple determination of the expansion of both body and glaze in this instance would easily reveal whether or not a good glaze fit could be expected. If differences existed at some temperature above the annealing point of the glaze, no real difficulty would present itself.

In the actual case, however, expansion data on the body and glaze cannot be relied on to insure good fit in the final product, especially in the one-fire system. This is due to the formation at the interface of a layer whose properties hitherto have not been determined. The formation and presence of this interfacial layer, furthermore, changes the composition of the glaze and introduces errors into the calculations as has been shown by Merritt and Peters.[6]

The curves in Fig. 2 show that stress is developed from 1135°C to the softening point (approximately 830°C). If it is assumed that a fluid glaze develops no stress, then the logical conclusion is that this stress is due to a substance which has been cooled below its softening point. Such a substance could be the product of the pyrochemical reaction at the interface.

The curves show that the tension developed in the high-alumina glazes, B and C, is exceptionally high within this limited range of temperature. The low-alumina glaze, D, develops stress in compression rather than in tension in this range.

Many reasons for the development of this stress can be given, but the most important one lies in the fact that the composition of the glaze at the interface changes owing to the reaction of the glaze and the body. If any unique stresses were developed in this

[5] H. G. Schurecht and G. R. Pole, "Method of Measuring Strains Between Glazes and Ceramic Bodies," *Jour. Amer. Ceram. Soc.*, **13** [6] 369–75 (1930).

[6] G. E. Merritt and C. G. Peters, "Interferometer Measurements of the Thermal Dilatation of Glazed Ware," *ibid.*, **9** [6] 327–42 (1926).

zone between body and glaze, they probably would manifest themselves in a temperature range between the firing temperature of the piece and the softening point of the glaze. This seems to be reasonable if the interface is assumed to be a mixture of the body and the glaze.

The stress development near 830°C in each case is retarded, and from this point each curve quickly rises to a peak of maximum tension. The temperature at which this peak is reached varies, but it is about 600° to 650°C. In a recent article on observations of stresses in cooling glazed bodies using a dial gauge, Rigby and Bullin[7] stated that "the slight irregularities in the curves in the neighborhood of 600°C were probably due to temperature gradients in the specimen when it was undergoing the $\alpha \rightarrow \beta$ quartz transformation and were not due to any stresses introduced by the glaze." This may or may not be the explanation for the development of this peak near 600°C. From the expansion curves of the unglazed body and glaze D (Fig. 3), there is a considerable difference in the rate of expansion between these substances in this temperature range, and some indication of this difference may be expected in the cooling curves of the glazed body.

Slow cooling was believed to reduce the danger of crazing within this zone. Glaze A, which normally was badly crazed, on cooling was held at a temperature of 850°C for forty-five hours. During this time, the stress increased to a point approximately equal to that shown by glaze C. Glaze C, in other words, has a value of 10 kg. per sq. mm. stress in tension at 850°C, whereas glaze A, before annealing, had a value of only 2 kg. per sq. mm. stress in tension at the same temperature. Holding glaze A at this temperature increased the stress in tension to a value of 9.4 kg. per. sq. mm. From this point, glaze A was cooled to room temperature and followed closely the stress curve of glaze C. After this annealing run, the specimen was still slightly crazed, but the glaze had been transformed from a bright texture to a mat finish. Slow cooling had a tendency to devitrify the glaze.

The curves in Fig. 2, furthermore, show that after this peak of tension is near 650°C, the stresses diminish somewhat, level off, and finally increase slightly at a low temperature. The expansion curves in Fig. 3 predict this to a remarkable degree. At a temperature between 100° and 250°C, a difference in the rate of expansion between the unglazed body and glaze D is indicated. Rigby and Bullin,[7] in the particular group of bodies and glazes they have studied, show that the greatest stress development occurs in the range of 100° to 300°C and is "mainly ascribed" to the cristobalite content of the body.

VI. Conclusions

In the specific points of the field studied, a 1 to 3.5 ratio of alumina to silica (glaze C) gives a glaze which is extremely high in tension; no crazing results, however, because of the high elastic strength of the crystalline structure resulting from high alumina content. A decrease in the alumina content not only lowers the glaze stress in tension but increases the danger of crazing because of the formation of lower alumina glazes (semimats, glazes B and A), which are also elastically weaker. When a ratio of alumina to silica near 1 to 6.5 (glaze D) is reached, a clear glaze in compression results with little or no danger of crazing. Further increases of silica to a 1 to 10 ratio (glaze E) result in a slow movement of the glaze stress toward tension. This shows why the old rule of increasing the silica content of glazes to reduce crazing cannot be applied indiscriminately.

In considering factors for good glaze fit, it is important to remember that the formation of an interfacial layer between the body and glaze changes the composition of the glaze and introduces errors into calculations from expansion curves which may be misleading.

Acknowledgement

The author wishes to express his thanks to F. H. Norton for his valuable advice and criticism.

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[7] G. R. Rigby and L. Bullin, "Stresses Introduced During Cooling of Glazed Bodies," *Trans. Brit. Ceram. Soc.*, **38** [2] 152–72 (1939); *Ceram. Abs.*, **18** [7] 188 (1939).

HIGH-TEMPERATURE VISCOSITIES OF SODA-SILICA GLASSES*

By H. R. Lillie

Abstract

A careful study of the viscosities of glasses composed of silica and between 22 and 40% soda shows that viscosity-composition isotherms are smooth curves. The sharp minima at about 34% Na_2O (and possibly at about 26% Na_2O) observed by Preston[1] are found to be entirely absent. Neither time nor shearing stress has any effect upon observed viscosities in the region investigated as long as temperature constancy has been established. A study of deviations, *i.e.*, of individual points from the smooth isotherms, shows that these are all within the expected limits of experimental error.

I. Introduction

The nature of glass from the standpoint of whether or not it is composed of (or even contains) groups of atoms in the form of discrete molecules has been a subject of great interest and some controversy for several years. Viewing it as simply the siliceous counterpart of well-known noncrystalline organic and elementary substances, glass is thought to be an amorphous solid, and, considering the tendency of most glasses to precipitate crystals under proper conditions, the substance may be thought of as a supercooled liquid or supersaturated solution. That all three of these terms, in this instance, may be synonymous need not be discussed here; the fact remains that neither concept entirely precludes the possibility of dissociated molecules occurring in the glassy phase. A large number of similar molecules can conceivably exist in the amorphous solid condition; in fact, if the viscosity at the melting point is high enough, such an amorphous state might easily be formed. Even in a mixture of different kinds of molecules, it is at least possible that they can exist side by side either above the saturation temperature or below it, provided the fluidity and time requirements essential for separation and crystallization of some component are not met.

There seems to be no direct means of detecting the presence of such discrete molecules. Studies are limited therefore to the various physical properties of molten or cold glasses, and from these studies one may judge whether the compounds can exist, and if so whether they are present, as such, in great quantity.

Such a study has been made by Preston,[1] who measured viscosities of molten soda-silica mixtures and discovered a sharp minimum in the viscosity-composition isotherms corresponding to the composition of sodium disilicate, $Na_2O \cdot 2SiO_2$. He attributes this minimum to the presence of the disilicate molecule in the glasses. On either side of the critical composition, large associates are presumed to be formed between the disilicate and either silica or the metasilicate; as the disilicate composition is approached, these associates become progressively smaller. There results, at the critical composition, a less associated (and therefore more fluid) material, the disilicate itself.

In Zachariasen's early experiments on X-ray diffraction from cold glass,[2] he found that certain rules applied to the atomic arrangement in vitreous silicates. These rules (with which Warren[3] is in complete accord) are (*a*) the silicon ion is always surrounded tetrahedrally by four oxygen ions and never by any other number; (*b*) each and every oxygen ion is shared between the silicon ion and some other positive body, such as a sodium or a second silicon ion; and (*c*) no two adjacent silicons can share more than one oxygen ion between them.

In any silicate glass, the observance of these rules gives rise to a vast network of tetrahedra joined only at their apices and including such other ions (Na, Ca, Pb, or the like) as may be present. If there are no such ions, *i.e.*, if pure silica is being considered, there is a network of tetrahedra presenting no great symmetry but easily transformable into a variety of ordered crystal arrangements, the form depending on the temperature. It must be remembered, however, that the $Si \cdot O_4$ tetrahedron is the outstanding and never-changing characteristic of the silicon-oxygen mechanism. From this fact, such a thing as a SiO_2 molecule is without meaning; the 1 to 2 ratio is approached only as the number of tetrahedra becomes very large.

So it is essentially with the sodium disilicate or metasilicate. At least six tetrahedra must be joined to make the former compound and at least three for the latter. Thus, speaking molecularly, these should be written $3Na_2O \cdot 6SiO_2$ and $3Na_2O \cdot 3SiO_2$, respectively.

Although these coördination rules are followed in the vast majority of cases, X-ray methods cannot prove that microscopic exceptions are entirely absent. Here and there in the glass, for instance, there may be two adjacent silicons temporarily sharing three oxygens, with the end charges taken up by two sodiums. There can be little doubt that such momentary unions happen occasionally, but, according to Warren,[3] their occurrence must be extremely rare. The configuration moreover must be less stable than the continuous net-

* Presented at the Forty-First Annual Meeting, American Ceramic Society, Chicago, Ill., April 18, 1939 (Glass Division). Received April 10, 1939.

[1] Eric Preston, "Viscosity of Soda-Silica Glasses at High Temperatures and Its Bearing on Their Constitution," *Jour. Soc. Glass Tech.*, **22** [90] 45–81 (1938); *Ceram. Abs.*, **18** [1] 18 (1939).

[2] W. H. Zachariasen, "Atomic Arrangement in Glass," *Jour. Amer. Chem. Soc.*, **54** [10] 3841–51 (1932); *Ceram. Abs.*, **12** [4] 145 (1933).

[3] B. E. Warren and J. Biscoe, "Fourier Analysis of X-Ray Patterns of Soda-Silica Glass," *Jour. Amer. Ceram. Soc.*, **21** [7] 259–65 (1938).

work—otherwise the $Na_2O \cdot 2SiO_2$ units would accumulate until positively detected by the X-rays.

It may also be argued that the molecule $3Na_2O \cdot 6SiO_2$ is as acceptable as is $Na_2O \cdot 2SiO_2$, because no differentiation need be made between 3 to 6 and 1 to 2 ratios. The former, however, is a rather special configuration requiring a certain degree of accommodation from its immediate neighbors, and the extent of the defined field, therefore, is rather larger than is at first apparent. If thermal agitation at the liquidus temperature (874°C), furthermore, is violent enough to prevent a repetition of the configuration, it seems unlikely that the individual groups can survive in large numbers, *e.g.*, at 1400°C.

Preston's technique and the general apparent dependability of his work are so convincing as to make it as presumptive to attribute his observations to experimental error as it is difficult to reconcile them to the present notions of the nature of glass. Because the first step obviously was to make certain of the effect, the task of repeating the viscosity measurements was undertaken soon after the appearance of Preston's results in the literature.

Viscosity-composition isotherms found by the author will be briefly described and compared with those by Preston. Following this, for the benefit of those wishing to make a critical examination of the technique involved, that method employed in the present case will be described in sufficient detail. Further discussion of the general question of compounds in glass, however, will not be included here.

II. Comparison of Results

Figure 1 is taken directly from Preston's paper.[4] Attention is particularly directed to the sharp minimum occurring in each isotherm at 34% Na_2O by weight. This composition is interpreted as corresponding to $Na_2O \cdot 2SiO_2$ (33.95%). The magnitude of the effect, in terms of logarithmic values of viscosity, increases appreciably as higher temperatures are reached. This fact in itself is rather extraordinary because, aside from any consideration of the existence of molecules at 1400°C, such an increase in the log η temperature slope at 34% Na_2O would usually be construed as an indication of increased association, whereas the explanation of the minimum itself is predicated on a decrease in association at this composition.

Another less definite minimum appears at about 26% Na_2O and this also becomes somewhat more pronounced at the higher temperatures. Preston has some doubt as to the reality of this second minimum although its position is almost exactly that of the hypothetical $Na_2O \cdot 3SiO_2$ compound (25.52% Na_2O). His doubts seem justifiable as such a molecule would be an extremely complex and probably unstable group. If the rules which have been discussed are to be followed, the 1 to 3 ratio must be written $4Na_2O \cdot 12SiO_2$, the nature of which would be two tetrahedron groupings (similar to the disilicate configuration)

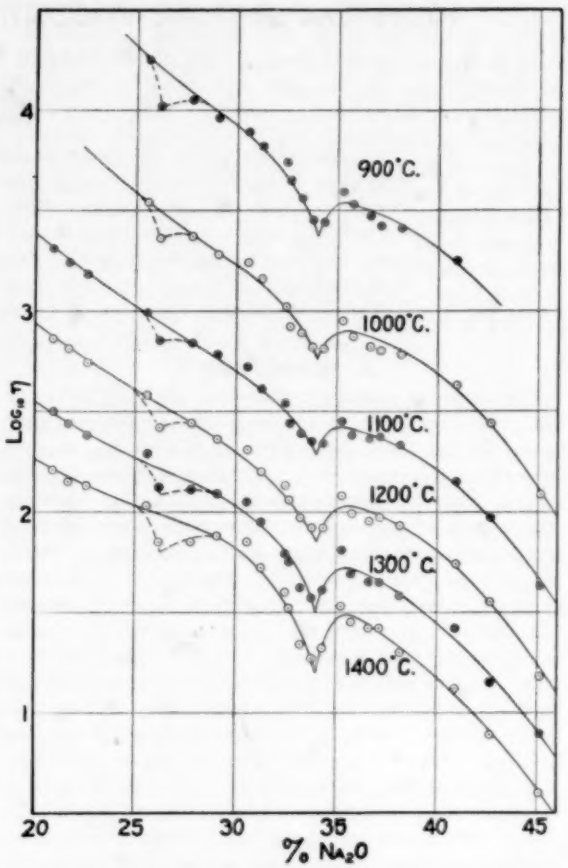

FIG. 1.—Viscosity-composition isotherms observed by Eric Preston; their outstanding feature is the sharp minimum at 34% Na_2O.

hinged together in the middle and surrounded by eight sodium ions.

An additional feature of Preston's family of curves, as mentioned previously, is that the minima, especially at 34% Na_2O, cannot be readily dismissed as experimental error; *e.g.*, the minimum at 1400°C involves a deviation from the smooth curve by a factor of some 2.5. Any errors in glass analysis furthermore cannot account for the effect.

Although the individual plotted points are rather scattered, this is to be expected and must not be used in arguing against the validity of the minima. Given the same data, any experimenter would place the curves essentially as Preston has done.

Figure 2 shows corresponding curves constructed after data of the writer. Just as Preston had little choice in drawing his isotherms, so the writer is restricted in the representation of his data; a family of smooth curves unquestionably is required. Deviations of individual points from the smooth lines of Fig. 2 are not radically different in magnitude from those of Preston's points from his curves; expected errors are the same in both cases. The failure of the author to observe any singular behavior (outside the expected limits of error) around 34% Na_2O cannot

[4] *Loc. cit.*, Fig. 11 (900° curve has been substituted for Preston's 950° curve).

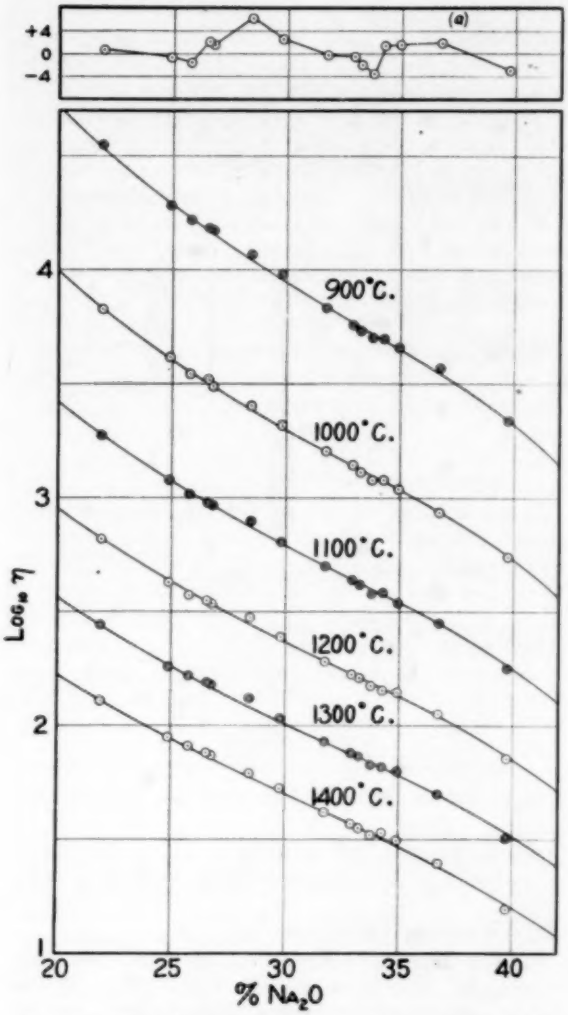

FIG. 2.—Viscosity-composition isotherms observed by the author; the minima featured in Fig. 1 are absent.

readily be ascribed to lack of care; it would seem illogical to discount in such manner the faithful adherence to smooth curves.

Figure 2(*a*) will be discussed in a subsequent part of this paper.

(1) Comparison of Curves

A direct comparison between the present results and those of Preston is in order. In Fig. 3, given for this purpose, the 1300°C curve has been chosen as representative. The agreement is satisfactory except for the central portion; the author welcomes this reassurance in the matter of calibration, etc., which serves as a starting point for clearing up the less fortunate discrepancies in the 34% region. It is interesting to note that Preston's questionable minimum at 26% was apparently caused by the unusually large error in two glasses (25.58 and 26.18% Na_2O). The algebraic mean deviation of these two points, from the smooth curve, is small. This cannot be said of the situation at 34% Na_2O; the two glasses near 32.5% might be overlooked, but the three between 33% and 34.5% deviate too widely.

In a recent paper by Ewell,[5] an attempt is made to compute from theory the variation of viscosity in soda-silica mixtures as a function of soda content. His treatment results in a curve which is concave upward throughout, whereas observed viscosities lead to relations which become concave downward above about 37% Na_2O. This inflection is minimized, but not entirely avoided, by plotting Na_2O to SiO_2 ratios in the manner indicated by Ewell's theory. The results in the present study concur with previous ones in this feature, but they have not been extended far enough (in soda content) to substantiate definitely the rapid decrease exhibited by Preston's curves.

(2) Conclusions

In the binary system, Na_2O–SiO_2, between 20 and 40% Na_2O by weight, a smooth relation exists between composition and viscosity at any given temperature above that of the liquidus. There seems to be no explanation at the present time for the spurious results reported by Preston in which the outstanding feature is a sharp minimum occurring in each isotherm approximately at 34% Na_2O. The secondary minimum at 26% Na_2O is entirely unsubstantiated.

III. Technical Details

(1) Raw Materials

All glasses were melted from the same large stocks of fine-ground quartz sand and chemically pure Na_2CO_3.

The SiO_2 is a specially washed, powdered quartz and contains impurities totaling less than 0.015%, consisting chiefly of oxides of iron, titanium, and aluminum. The sand is of the highest purity readily available.

[5] R. H. Ewell, "Theoretical Consideration Concerning the Viscosity of Binary Silicate Glasses," *Rheology Leaflet*, No. 7, p. 8 (November, 1938).

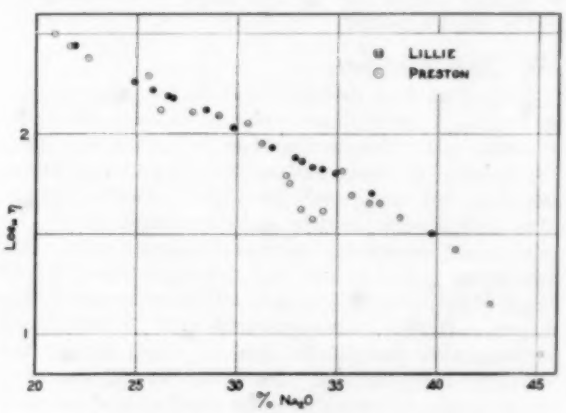

FIG. 3.—Direct comparison of present data with those of Preston at 1300°C; except for the disilicate region, the agreement is satisfactory.

The Na_2CO_3 was obtained from J. T. Baker Chemical Company; the following condensed analysis is quoted from its label: insoluble matter 0.005, K 0.02, Fe 0.001 and Pb, Ca, Mg, As 0.000%. All other impurities are either SiO_2 or of volatile nature.

Required weights were computed on the basis of perfect dryness; in their analyses, the glasses accordingly departed somewhat from the intended compositions. The materials were weighed, mixed thoroughly by shaking in a large glass container, and were used immediately. Each batch was computed to yield 700 grams of glass when finished.

(2) Melting Equipment

The furnace used in batch-melting was platinum-rhodium wound and similar in essential respects to that employed in the viscosity determinations. The crucible was of platinum-rhodium, cylindrical in shape, and of about 350-cc. capacity. The platinum-rhodium stirring rod, referred to later, was about 5 mm. in diameter, about 15 cm. long, and was fastened to a nickel handle. Special tongs were provided to remove the crucible from the furnace for each stirring. The finished glass was poured on a platinum plate about 12 cm. square and 3 mm. thick.

(3) Melting Schedule

The furnace was operated at about 1325°C during the time required to introduce the batch. The latter was accomplished by several additions, progressively smaller, until the entire mix had been melted down, usually a matter of some five hours. The control setting was raised immediately to 1425°C, the natural heating rate of the furnace being low enough to prevent violent boiling and overflow of the glass.

Upon reaching the upper temperature, the melt was stirred vigorously three or four times (depending on fluidity) with the stirring rod. Following each stirring, about 45 minutes were allowed for thorough reheating.

After the last stirring and subsequent refining, the glass was poured out on the platinum plate. Three pours were required, resulting in three disks about 11 cm. in diameter and 1 cm. thick. The glass was essentially bubble-free and appeared to be homogeneous in other respects.

(4) Glass Analyses

Each glass was analyzed for soda four times, twice as originally melted and twice as it came from the viscosity run. For compositions containing less than 30% Na_2O, the latter was determined gravimetrically; titration was employed for higher Na_2O contents. The analyst was familiar with the nature of the research and accordingly exercised extreme care. The maximum spread in the four determinations for any single glass was 0.36%, and in all but two cases it was less than 0.20%. An appreciable part of this spread represents in general the loss of alkali during the viscosity determination, the latter figure averaging nearly 0.1%. Disregarding the possibility of errors in absolute values, it is concluded that the relative analyses (averaged) were probably correct to less than 0.1% Na_2O. All soda contents were corrected for loss on ignition observed in a separate sample of the ground glass taken at the same time as the analysis sample.

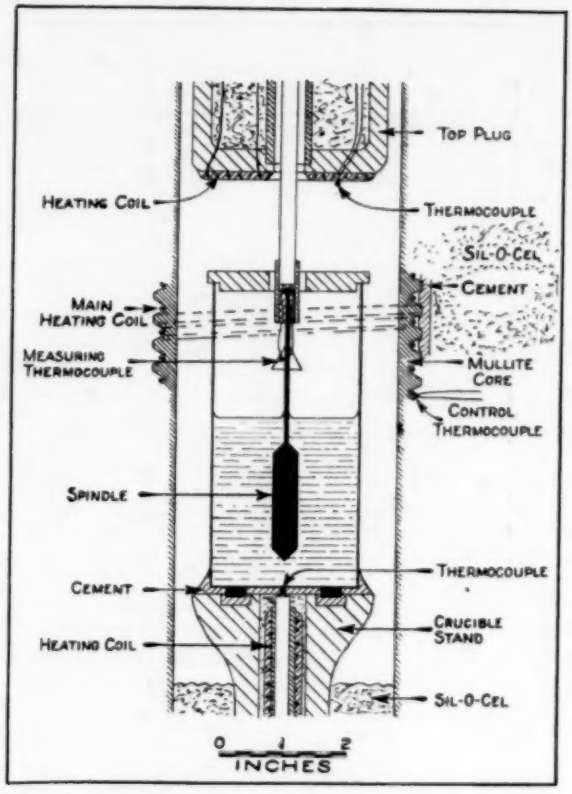

FIG. 4.—Partial longitudinal section of viscosity apparatus.

(5) Viscosity Technique

The technique, generally speaking, did not differ essentially from that described in 1929.[6] Several minor refinements have been added to the apparatus since that time, but these need no comment here. Figure 4 represents a longitudinal section of the present equipment, showing the platinum crucible and spindle in position and indicating the various heating elements and thermocouples involved in temperature control and measurement. Control was attained through a thermocouple situated near the main heating element, and uniformity was established by the upper and lower auxiliary heating elements and their individual thermocouples; readings of the latter were compared with that of the measuring thermocouple located directly on the spindle. Before and after each viscosity determination, the e.m.f. of the measuring couple was observed on a Leeds and Northrup type K potentiometer accurate to less than 0.001 mv. Special care was taken during the present work to keep all three thermocouples in good condition; during the progress of the work, three different measuring couples were employed, each bearing a calibration by the National Bureau of Standards.

[6] H. R. Lillie, "Viscosity Measurements in Glass," *Jour. Amer. Ceram. Soc.*, **12** [8] 516–29 (1929).

(6) Schedule Followed

The schedule is given for viscosity determinations for each glass.

First Day: The crucible and spindle were thoroughly cleaned from the preceding run, and the crucible, if necessary, was shaped by tapping over a form. The required quantity of glass was weighed out and introduced into the crucible, the latter then being cemented in place. When the cement was sufficiently dry, the furnace was lowered into place; a cap was placed on the crucible, and diatomaceous earth was introduced from the top to surround the crucible stand as indicated in the drawing. The crucible cover, top plug, and spindle assembly were next placed and centered. Sufficient current was allowed in the main heating element to produce a temperature of about 900°C by the following morning.

Second Day: The furnace was immediately placed on automatic control and set for 1300°C. Upon arrival at this temperature, the spindle was lowered into the glass, and other final adjustments were made. The temperature was increased to 1400°C and allowed to control at this point for at least one hour before the initial viscosity measurement was made.

The viscosity is the average of values computed for three speeds of crucible rotation, both directions of rotation being used in each case. Only in extremely rare instances did the difference in result between the fastest and slowest speed amount to as much as 2%. The speeds were approximately 35, 20, and 12 seconds per revolution.

During this second day, five or six temperatures were disposed of; at least one hour elapsed after a temperature was reached by the control couple before viscosity readings were made. After the last temperature, the furnace was left overnight at about 1100°C.

Third Day: The remaining temperatures were run, following the same technique already described. Whenever light suspensions were used, as in the present case, viscosities in excess of about 700 poises were measured by observing the speed of spindle drift toward zero.

After the last measurement was made, the temperature was raised to about 1250°C to withdraw the spindle to a position above the glass. All current was then turned off. The following day, the crucible was reheated in a different furnace, and the glass was poured out on the platinum plate. The apparatus was then made ready for the next run.

IV. Special Runs

During the course of three of the viscosity runs, special observations were made in order to demonstrate three facts known previously to the author but of particular significance in the present work. These facts, and the data to demonstrate them, are as follows:

(1) Provided sufficient time is allowed to insure proper temperature conditions, the benefit to be derived from further delay in taking readings is negligible. This is not in accord with Preston's contention that elapsed time is important in observing true results.

In run No. 4 on glass No. 10 (33.24% Na_2O), the data included the following:

	Time	Temp. (°C)	$\log_{10}\eta$
(*a*)	11:50 A.M.	1391	1.577
(*b*)	1:30 P.M.	1392	1.594
(*c*)	3:30	1290	1.917
(*d*)	4:10	1290	1.894
(*e*)	5:00	1189	2.246
(*f*)	10:20	1187	2.249
(*g*)	8:40 A.M.	1188	2.263
(*h*)	11:40	988	3.190
(*i*)	1:20 P.M.	987	3.190
(*j*)	2:40	889	3.822
(*k*)	3:30	887	3.826

Observations (*a*) through (*f*) were made September 15, and (*g*) through (*k*) September 16, 1938.

Observation (*a*) was purposely made before the usual time was allowed for temperature stability, but it is not radically different from observation (*b*). It must be remembered that in this type of work even a 4% error need not cause alarm. Observations (*e*) through (*g*) show that an overnight stand gives results substantially no different from the initial determination. The other observations are in accord with the fact originally stated.

(2) Because the spindle is of the type employed at present, its vertical position along the axis is not a critical factor in determining torque. No effort is made to readjust the distance from crucible bottom to spindle for each temperature; the setting for a distance of 1 cm. at an average temperature is left undisturbed throughout the run. It was considered pertinent therefore to conduct a few special tests, although previous observations had disposed of the matter to the author's satisfaction.

The following data were recorded during run No. 15 on glass No. 15 (39.74% Na_2O):

	Spindle distance (cm. from bottom of crucible)	Temp. (°C)	$\log_{10}\eta$
(*a*)	1.00	1246_8	1.686_8
(*b*)	0.60	1246_2	1.688_0
(*c*)	1.40	1245_8	1.688_4
(*d*)	1.00	1245_4	1.691_1

During the tests, the temperature dropped 1_1°C and the $\log_{10}$ of viscosity increased by 0.004_8, a rate of about 0.004_1 per degree. The rate at 1245°C, read from the finished viscosity curve for this glass, is 0.0035 per degree. The agreement is satisfactory; it may also be concluded from these data that the torque increases slightly as the spindle is lowered but that the effect can scarcely be detected.

(3) During the progress of any run, two separate suspension constants are used and two rather different methods are employed (constant torque, due to crucible rotation, and the logarithmic decrement of the spindle's return toward its equilibrium position with the crucible stationary). To demonstrate that these circumstances do not introduce error, the following observations are quoted from run No. 2 on glass No. 13 (34.92% Na_2O):

	Method	Suspension constant	Temp. (°C)	$\log_{10}\eta$
(*a*)	Rotation	1.015×10^3	1281	1.865
(*b*)	"	1.235×10^4	1281	1.857
(*c*)	"	1.235×10^4	1044	2.812
(*d*)	Decrement	1.015×10^3	1044	2.816

These data speak for themselves. Obviously all relative calibrations are essentially correct. Suspensions are calibrated by the torsion pendulum method; their constants are expressed in dyne-centimeters per radian.

V. Results

(1) Composition

Table I gives the analyses of the glasses used (mean values as mentioned above).

TABLE I

Glass No.	Na_2O by weight (%)	Glass No.	Na_2O by weight (%)
1	21.91	9	32.91
2	24.89	10	33.24
3	25.78	11	33.77
4	26.57	12	34.27
5	26.79	13	34.92
6	28.46	14	36.73
7	29.79	15	39.74
8	31.74		

(2) Viscosity Data

Complete viscosity observations for the entire series of glasses are given in Table II.

(3) Interpolated Viscosities

Observed viscosities for each glass were first plotted logarithmically against temperature. Values at certain reference temperatures were then read directly from the curves so obtained. These interpolated values are given in Table III.

TABLE III

Glass No.	Na_2O content (%)	$\log_{10}\eta$ at 900°C	1000°C	1100°C	1200°C	1300°C	1400°C
1	21.91	4.55	3.83	3.28	2.82	2.44	2.11
2	24.89	4.29	3.62	3.08	2.63	2.26	1.95
3	25.78	4.22	3.55	3.02	2.58	2.22	1.91
4	26.57	4.19	3.52	2.98	2.55	2.19	1.88
5	26.79	4.18	3.49	2.97	2.54	2.18	1.87
6	28.46	4.07	3.41	2.90	2.48	2.12	1.79
7	29.79	3.98	3.32	2.81	2.39	2.03	1.72
8	31.74	3.84	3.21	2.70	2.28	1.93	1.62
9	32.91	3.76	3.15	2.64	2.23	1.88	1.57
10	33.24	3.74	3.12	2.62	2.21	1.87	1.55
11	33.77	3.71	3.08	2.58	2.18	1.83	1.52
12	34.27	3.70	3.08	2.59	2.16	1.82	1.53
13	34.92	3.66	3.04	2.54	2.15	1.80	1.50
14	36.73	3.57	2.94	2.45	2.05	1.70	1.40
15	39.74	3.34	2.74	2.25	1.86	1.51	1.20

The values given in Table III were used to plot the curves of Fig. 2; the characteristics of these curves have already been discussed.

VI. Analysis of Deviations

In view of the fact that the points plotted in Fig. 2 deviate from the curves in such a manner as to suggest vaguely the presence of a minimum at about 34% Na_2O, it seemed advisable to examine the individual deviations in detail. The following kinds of average deviation were determined: arithmetical mean, algebraic mean, and maximum deviation for each of the reference temperatures and the algebraic mean for each of the fifteen compositions.

(1) Deviations as a Function of Temperature

Table IV shows the results as functions of temperature, the upper figure being in terms of percentage viscosity and the lower in terms of °C.

The arithmetical mean would not be changed by moving the curves vertically and parallel to themselves but gives a good estimate of the errors involved in measurements if the smooth curves are essentially correct. The algebraic mean, on the other hand, could easily be adjusted to zero if the curves were so made as to best represent the points even though they were not of the proper type. Smooth curves obviously could be drawn through Preston's points in such a way as to eliminate the algebraic mean deviation, but such curves would not correctly represent his data. These figures, therefore, simply indicate that the present curves could, to advantage, be somewhat higher but that they are not far enough off to cause concern. Some of the figures for maximum deviation would be decreased somewhat by such a shift of the curves.

(2) Deviations as a Function of Composition

Table V gives the algebraic mean deviations for the several compositions in terms of viscosity and temperature.

TABLE V

Glass No.	Algebraic mean deviation	Glass No.	Algebraic mean deviation
1	+0.7% +0.22°	10	−1.9% −1.77°
2	−0.7% −0.88°	11	−3.5% −3.48°
3	−1.6% −1.18°	12	+1.4% +1.45°
4	+2.1% +1.95°	13	+1.6% +2.05°
5	+1.6% +1.68°	14	+1.9% +1.90°
6	+6.2% +6.08°	15	−2.8% −3.80°
7	+2.6% +2.35°	Arithmetical mean	1.9% 1.95°
8	−0.3% −0.25°	Algebraic mean	+0.4% +0.41°
9	−0.5% −0.23°	Maximum deviation	+6.2% +6.08°

Figure 2(*a*) shows these percentage values plotted against composition. The deviations do not appear to be random in character but give a further hint of breaks at about 26 and 34% Na_2O. Such a conclusion, however, must be drawn with extreme caution, as all deviations are so small that a scale out of proportion to their accuracy must be used to represent them.

TABLE II

Glass No. 1 (run No. 13, Nov. 21 and 22, 1938) 21.91% Na_2O by analysis

(°C)	$Log_{10}\eta$
1406	2.092
1360	2.240
1309	2.406
1258	2.591
1207	2.787
1155	3.015
1078	3.385
1003	3.812
927	4.339
850	4.968

Glass No. 2 (run No. 12, Nov. 16 and 17, 1938) 24.89% Na_2O by analysis

(°C)	$Log_{10}\eta$
1404	1.944
1357	2.087
1305	2.251
1256	2.426
1206	2.613
1119	2.986
1046	3.357
970	3.801
893	4.349
820	4.974

Glass No. 9 (run No. 3, July 6 and 7, 1938) 32.91% Na_2O by analysis

(°C)	$Log_{10}\eta$
1401	1.573
1362	1.688
1320	1.816
1280	1.944
1239	2.085
1197	2.236
1096	2.659
1091	2.674
989	3.203
908	3.723
866	4.011
824	4.375
785	4.745

Glass No. 10 (run No. 4, Sept. 15 and 16, 1938) 33.24% Na_2O by analysis

(°C)	$Log_{10}\eta$
1392	1.585
1290	1.905
1188	2.253
1084	2.689
988	3.190
888	3.824

Glass No. 3 (run No. 11, Nov. 9 and 10, 1938) 25.78% Na_2O by analysis

(°C)	$Log_{10}\eta$
1403	1.902
1356	2.036
1307	2.202
1254	2.387
1201	2.572
1152	2.778
1104	3.003
1003	3.535
904	4.197
800	5.108

Glass No. 4 (run No. 7, Oct. 20 and 21, 1938) 26.57% Na_2O by analysis

(°C)	$Log_{10}\eta$
1395	1.900
1354	2.026
1311	2.155
1270	2.296
1230	2.439
1189	2.604
1091	3.034
990	3.582
910	4.129
840	4.698
800	5.085

Glass No. 11 (run No. 1, June 28 and 29, 1938) 33.77% Na_2O by analysis

(°C)	$Log_{10}\eta$
1404	1.513
1365	1.633
1323	1.778
1282	1.894
1240	2.033
1199	2.182
1094	2.616
992	3.127
911	3.636
869	3.932
827	4.279
787	4.649

Glass No. 12 (run No. 6, Oct. 12 and 13, 1938) 34.27% Na_2O by analysis

(°C)	$Log_{10}\eta$
1393	1.545
1352	1.663
1312	1.787
1269	1.924
1231	2.046
1192	2.198
1092	2.618
992	3.127
912	3.622
871	3.909
831	4.228

Glass No. 5 (run No. 9, Oct. 31 and Nov. 1, 1938) 26.79% Na_2O by analysis

(°C)	$Log_{10}\eta$
1403	1.852
1361	1.974
1324	2.092
1282	2.230
1232	2.412
1180	2.616
1102	2.960
1002	3.476
903	4.142
802	5.021

Glass No. 6 (run No. 10, Nov. 3 and 4, 1938) 28.46% Na_2O by analysis

(°C)	$Log_{10}\eta$
1403	1.782
1354	1.930
1302	2.106
1253	2.246
1201	2.455
1152	2.659
1103	2.884
1003	3.391
903	4.042
801	4.926

Glass No. 13 (run No. 2, June 30 and July 1, 1938) 34.92% Na_2O by analysis

(°C)	$Log_{10}\eta$
1405	1.477
1363	1.596
1322	1.721
1281	1.861
1236	1.993
1197	2.141
1157	2.300
1044	2.814
911	3.594
867	3.904
828	4.227
785	4.639

Glass No. 14 (run No. 14, Nov. 28 and 29, 1938) 36.73% Na_2O by analysis

(°C)	$Log_{10}\eta$
1410	1.362
1361	1.516
1311	1.673
1259	1.842
1209	2.010
1132	2.316
1058	2.658
983	3.040
907	3.516
831	4.095

Glass No. 7 (run No. 8, Oct. 25 and 26, 1938) 29.79% Na_2O by analysis

(°C)	$Log_{10}\eta$
1402	1.719
1361	1.842
1317	1.961
1282	2.097
1240	2.242
1199	2.395
1098	2.822
1001	3.315
951	3.629
899	3.985
851	4.371

Glass No. 8 (run No. 5, Sept. 28 and 29, 1938) 31.74% Na_2O by analysis

(°C)	$Log_{10}\eta$
1399	1.626
1301	1.930
1260	2.066
1220	2.213
1176	2.374
1079	2.805
1009	3.154
949	3.511
889	3.916
848	4.243

Glass No. 15 (run No. 15, Dec. 1, 2, and 3, 1938) 39.74% Na_2O by analysis

(°C)	$Log_{10}\eta$	(°C)	$Log_{10}\eta$
1397	1.202	1194	1.877
1346	1.356	1096	2.280
1297	1.513	992	2.793
1246	1.689	891	3.402
		793	4.188

TABLE IV

	900°C	1000°C	1100°C	1200°C	1300°C	1400°C
Arithmetical mean deviation from curve	3.5% 1.94°	1.7% 1.29°	1.3% 1.31°	2.0% 2.26°	2.2% 2.83°	2.3% 3.32°
Algebraic " " " "	+1.5% +0.85°	+0.3% +0.23°	−0.3% −0.31°	0 +0.02°	0 0	+1.2% +1.70°
Maximum deviation from curve	+7.2% +4.2°	±4.7% ±3.5°	+5.9% +5.3°	+7.2% +7.8°	+8.4% +10.6°	±4.7% ±6.9°

(3) Expected Errors

To gain a better notion of the importance that can be reasonably placed on the graph in Fig. 2(*a*), the following consideration has been given to what errors may be reasonably expected.

(*a*) *Composition:* As previously stated, it is believed that the chemical analyses represent the relative composition (from glass to glass) to an accuracy of ±0.1% Na_2O. On the average, such a deviation in composition is equivalent to a change in viscosity of about 1.5%. As this represents the generally expected maximum from this source, the average of many viscosity deviations probably would not exceed 1%, and the maximum individual deviation should not exceed ±2.5%.

(*b*) *Viscosity Measurements:* Speaking only of *relative* values and neglecting errors in reading temperatures, the viscosity measurements are probably subject to a maximum error of ±2.5% and an average error of about 1.3%.

(*c*) *Temperature Measurements:* At a representative temperature (1200°C), the measurement of relative temperatures should be accurate to ±2°C. The average of many deviations from this source might be as high as 1.5° (equivalent to a viscosity error of 1.5%) and the maximum should not exceed 4°C (or 4%).

These possible errors are tabulated as follows:

Contributing factor	Equivalent error in viscosity (av. %)	(max. %)
Composition	1.0	2.5
Viscosity	1.3	2.5
Temperature	1.5	4.0
Total	3.8	9.0

Because it rarely happens that these errors are cumulative, the figures should be revised downward so that the expected deviations will be about 2.5% on the average and about 6% as a maximum.

A comparison of these data with Fig. 2(*a*) shows that the mean deviation in the latter is about 2% and the maximum is about 6%. Attention is again directed to a comparison between this 6% maximum deviation from smooth curves and the several-fold deviation observed by Preston at 34% Na_2O.

Inasmuch as some slightly different family of smooth isotherms obviously could reduce the observed deviations to somewhat smaller values, it is safe to say that experimental error can account for all irregularities. Although it cannot be positively proved from these data that no singular points exist at special compositions, it is contended that such points *can* be absent or that the extent of their irregularity must be very small indeed.

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VANADIUM AS A GLASS COLORANT*

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ABSTRACT

Vanadium, as a glass colorant, acts much like chromium. Ordinarily it leads to green tints which are due to the superposition of the green of trivalent vanadium and the yellow of pentavalent vanadium. Large excess of alkali leads to the formation of colorless vanadates. Under special conditions, solarization may be used to develop the lavender color of bivalent vanadium. The effect of melting conditions and changes in the base glass composition on the colors is discussed.

I. Introduction[1]

Vanadium has been the least used of that group of eight transition elements in the first long series of the periodic chart which provides the fundamental glass coloring agents. The reason is that the greenish tints which it ordinarily forms may be obtained more economically with iron, chromium, or copper or combinations of these. Some special applications of vanadium, however, may lead to increased interest in its use as a colorant and for information which it supplies about the chemistry of glass.

Vanadium should correspond chemically to nitrogen, phosphorus, arsenic, and antimony because of its five outer valence electrons. Actually, it does form oxides with valences of five, four, three, two, and possibly one, just as nitrogen does. It also forms ortho-, pyro-, meta-, and poly-vanadates in a profusion almost as great as the various radicals formed by pentavalent phosphorus, and it resembles phosphorus in its tendency to form glassy vanadium pentoxide. In appearance, however, vanadium compounds resemble more closely those of their neighboring transition elements, *viz.*, iron and (especially) chromium. Bivalent vanadium is a powerful reducing agent having lavender-colored salts. Trivalent vanadium forms green salts, which

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[1] In addition to the footnote citations, the authors have given the following references:

(*a*) J. W. Mellor, Modern Inorganic Chemistry, 8th ed. Longmans, Green, & Co., London, 1933.

(*b*) W. Weyl and E. Thümen, "Constitution and Color of Chromium Glasses," *Sprechsaal*, **66** [12] 197–99 (1933); *Ceram. Abs.*, **13** [6] 146 (1934).

(*c*) W. Weyl, "Chemistry of Colored Glass: I–III," *Glass Ind.*, **18** [3] 73–78; [4] 117–20; [5] 167–71 (1937); *Ceram. Abs.*, **16** [6] 170; [7] 201; [8] 239 (1937).

also act as reducing agents and are used in analytical chemistry. Quadrivalent vanadium salts are blue. They are the usual end point when lower salts are oxidized by air. Quadrivalent vanadium is usually present as a vanadyl $(VO)^{++}$ which corresponds to the uranyl radical. Pentavalent vanadium forms a yellow-to-brown oxide which resembles chromic acid (CrO_3), but because of its acidic nature, it usually forms in solutions the essentially colorless metavanadate anion, $(VO_3)^-$.

Fuwa,[2] one of the first authors to make a complete study of coloring oxides, devoted a special paper to vanadium, which is the only modern scientific paper to discuss this element as a colorant for glass. He found an equilibrium to exist between pentavalent and trivalent vanadium.

In studying the reactions of a coloring agent, two main groups of factors must be considered, *viz.*, (1) the influence of melting conditions (time-temperature history and furnace atmosphere) and (2) the effect of changes in the composition of the base glass.

II. Influence of Melting Conditions

Glass compositions ordinarily do not vary much. Experience has shown that those colorants which occur in several different states of valence are influenced chiefly by the melting conditions. The colors from cobalt and nickel are nearly independent of melting temperatures or composition of furnace atmosphere. Iron, on the other hand, which occurs both in its divalent and trivalent forms in glass, gives rise to a color which depends greatly on the melting conditions. The characteristic greenish iron color, for instance, has a strong tendency to turn more bluish if the temperature during fining is increased or if the fining period for any reason is prolonged. Reducing furnace atmospheres or carbon compounds in the batch similarly affect the color.

To determine the class to which vanadium belongs, it was introduced in the form of vanadium pentoxide into ordinary soda-lime glass and the usual yellowish green color was obtained. Upon remelting under reducing conditions or heating for a long time up to 1500°C, the same glass became a pure emerald green. The absorption curves for the two forms are given in Fig. 1.

A close resemblance is noticeable between the absorption curves of the vanadium glasses and those of chromium glasses (Fig. 2.). The main difference seems to be that vanadium has a strong absorption band in the near infra-red and that chromium glasses have a high transmission in this region.

The absorption of a chromium glass melted under oxidizing conditions has been found to consist of a superposition of two absorption spectra, *viz.*, that of a green Cr^{3+} ion and that of a yellow Cr^{6+} ion. The addition of reducing agents leads to the decomposition of the hexavalent ion and a greener glass. A corresponding reaction seems to occur in the case of glass colored by vanadium. The yellowish green color obtained under oxidizing conditions may be broken down into two separate absorption centers, one of which has an absorption in the violet region of the spectrum extending into the ultra-violet. This component decomposes under reducing conditions to the lower valence state which has a maximum transmission in the green, and a purer green results. Under suitable conditions, however, the lower valent absorption center may be converted into the state which has its absorption in violet, and a pure yellow glass can be obtained. This pure yellow color has been obtained by the authors by dissolving vanadium pentoxide carefully in a low melting glass at the minimum temperature. When the temperature was raised, larger amounts of the green constituent occurred in proportion to the time-temperature history of the glasses as well as a noticeable evolution of oxygen.

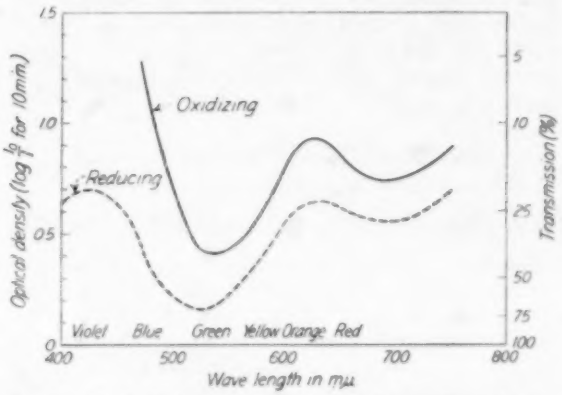

FIG. 1.—Typical absorption spectrum of vanadium glasses

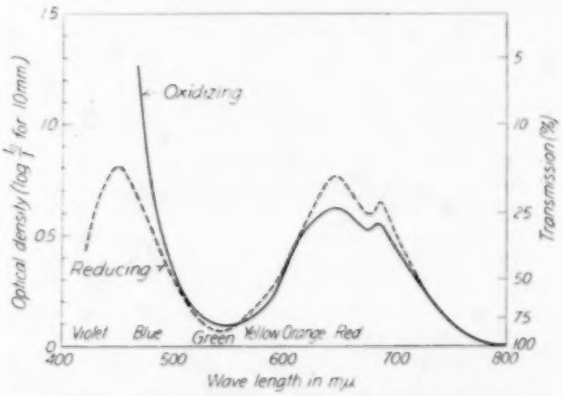

FIG. 2.—Typical absorption spectrum of chromium glasses.

III. Influence of Composition

The changes in an absorption spectrum caused by the environment may be divided into two groups of factors. The first deals with the electric stray fields which originate in the charges on the surrounding ions and molecules and cause the absorption to be smeared out. For one of the best examples of this effect, work by

[2] K. Fuwa, "Color Given to Glass by Vanadium," *Jour. Jap. Ceram. Soc.*, **369**, 236–40 (1923); *Ceram. Abs.*, 2 [11] 243 (1923).

Rosenhauer and Weidert[3] may be mentioned. These authors studied the absorption of the neodymium ion in different base glasses and succeeded in correlating the structure of the absorption curve with the sizes of the ions of the alkalis and alkaline earths.

The absorption characteristics of vanadium are not particularly influenced by this factor of stray electric fields as shown in Fig. 3. Changing the alkali from lithium to sodium or potassium does not produce any significant changes in the color or the absorption spectrum. The slight differences which are present could just as well be attributed to the varying ease of dissociation of oxygen from vanadium with variations in the viscosities and heat treatments of the base glasses during melting.

The second group of environmental factors are related to solvation of the absorbing ion. Owing to its electrical charge, each ion tries to surround itself by ions of the opposite charge or by dipoles which it causes to be oriented. This leads to an interaction of the outer parts of the electronic shells, which makes the absorption of a light quantum more or less difficult. In

[3] K. Rosenhauer and F. Weidert, "Spectral Absorption of Neodymium Glasses," *Glastech. Ber.*, **16** [2] 51–57 (1938); *Ceram. Abs.*, **17** [10] 326 (1938).

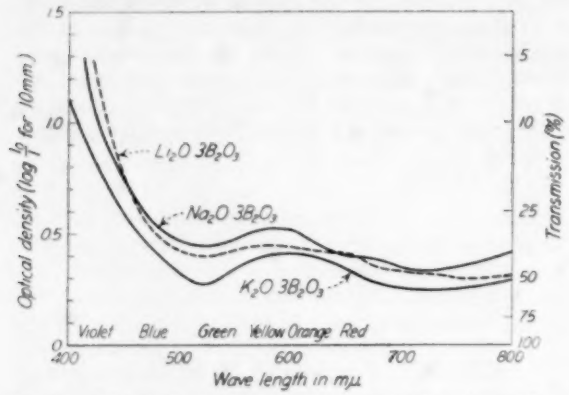

FIG. 3.—Effects of varying alkalis on vanadium absorption.

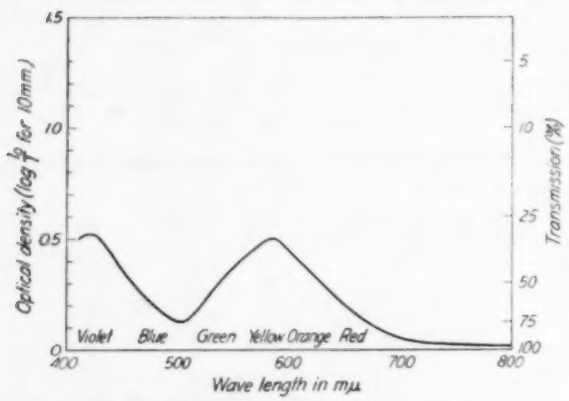

FIG. 4.—Absorption by Cr^{+++} in water.

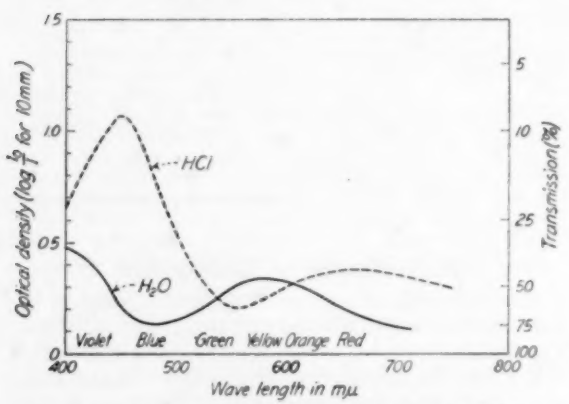

FIG. 5.—Absorption by V^{+++} in water and in HCl.

TABLE I

COLORS PRODUCED BY 1% V_2O_5 IN VARIOUS BASE GLASSES

Base glass composition	Color
Na_2O, CaO, $6SiO_2$	Mint green
K_2O, CaO, $6SiO_2$	" "
Li_2O, $2SiO_2$	Weak yellow
Na_2O, SiO_2	Colorless
Na_2O, $2SiO_2$	Weak yellowish green
Na_2O, $3SiO_2$	Green
Na_2O, $3\frac{1}{2}SiO_2$	"
Na_2O, $4\ SiO_2$	"
K_2O, SiO_2	Light yellow
K_2O, $2\ SiO_2$	Nearly colorless
K_2O, $3\ SiO_2$	Light green
K_2O, $4\ SiO_2$	Mint green
B_2O_3	Tan (gray)
Li_2O, $3\ B_2O_3$	Yellow-green
Li_2O, $4\ B_2O_3$	" "
Li_2O, $5\ B_2O_3$	Amber (gray)
Na_2O, $2\ B_2O_3$	Greenish yellow
Na_2O, $3\ B_2O_3$	Weak green
Na_2O, $4\ B_2O_3$	" "
Na_2O, $5\ B_2O_3$	Amber (gray)
K_2O, $2\ B_2O_3$	Colorless
K_2O, $3\ B_2O_3$	Bright green
K_2O, $4\ B_2O_3$	Gray-green
Na_2O, P_2O_5	Dark brown
Na_2O, $3\ P_2O_5$	Bright green
Na_2O, $\frac{1}{2}$ MgO, P_2O_5	" "
Na_2O, $\frac{1}{2}$ CaO, P_2O_5	Amber
Na_2O, $\frac{1}{2}$ ZnO, P_2O_5	"
Na_2O, $\frac{1}{2}$ SrO, P_2O_5	Yellowish green
Na_2O, $\frac{1}{2}$ BaO, P_2O_5	Green
Na_2O, $\frac{1}{2}$ PbO, P_2O_5	Dark amber
Na_2O, $\frac{1}{2}$ MgO, $2\ B_2O_3$	Weak yellow
Na_2O, $\frac{1}{2}$ CaO, $2\ B_2O_3$	" "
Na_2O, $\frac{1}{2}$ ZnO, $2\ B_2O_3$	" "
Na_2O, $\frac{1}{2}$ SrO, $2\ B_2O_3$	" "
Na_2O, $\frac{1}{2}$ BaO, $2\ B_2O_3$	" "
Na_2O, $\frac{1}{2}$ PbO, $2\ B_2O_3$	" "
Na_2O, $\frac{1}{2}$ MgO, SiO_2	Yellowish green
Na_2O, $\frac{1}{2}$ CaO, SiO_2	Lighter yellowish green
Na_2O, $\frac{1}{2}$ ZnO, SiO_2	" " "
Na_2O, $\frac{1}{2}$ SrO, SiO_2	" " "
Na_2O, $\frac{1}{2}$ BaO, SiO_2	Least color
Na_2O, $\frac{1}{2}$ PbO, SiO_2	Greenish yellow
Na_2O, SiO_2 +	Colorless
$0.3\ B_2O_3$	"
$0.6\ B_2O_3$	Weak yellowish green
$0.9\ B_2O_3$	Greener
Na_2O, $2\ SiO_2$ +	Weak yellowish green
$0.3\ B_2O_3$	Weak green
$0.6\ B_2O_3$	Green
$0.9\ B_2O_3$	Dark green
Na_2O, $2\ SiO_2$ +	Weak yellowish green
$0.01\ P_2O_5$	Yellowish green
$0.06\ P_2O_5$	Bluish green
$0.5\ P_2O_5$	Bright green

the absorption spectrum, this change will be expressed in a shift to longer or shorter wave lengths, depending upon the increase or decrease of solvation.

Some idea of the effect of such solvation forces may be obtained by comparing the absorption curves in Figs. 1 and 3, although there are other factors to be considered. A more impressive illustration may be seen in the absorption curves for aqueous solutions of the ions. Water has a very strong solvating action; for example, the hydrated chromium ion (Fig. 4) has an absorption which resembles that of the trivalent chromium ion in glass, but the peaks are shifted toward the short-wave end of the spectrum. The sharp structure of the same ion in glass is lacking.

When vanadium salts are dissolved in water, the weak green color of hydrated V^{+++} ion is obtained. The addition of hydrochloric acid dehydrates the vanadium ion considerably, and a distinct green color is obtained. Figure 5 represents the absorption curves of such solutions. In the aqueous solution, the first maximum found at 425 mμ in glass has moved into the ultra-violet, and the second maximum has moved from 625 to 590 mμ. Dehydration with HCl has displaced the maxima back to the right, and the increased absorption of blue and violet explains the much sharper green color.

For additional studies of the influence of the base glass composition upon the colors produced by vanadium, several series of glasses have been prepared with the results summarized in Table I. In each case, an amount of vanadium pentoxide was added to the batch equivalent to 1% V_2O_5 in the final glass. The furnace atmosphere was essentially constant and oxidizing.

Although the spectrophotometric curves of many of these glasses have been obtained, their characteristic features may be explained from the curves already given. Based on observations of the writers, the following conclusions are given:

(1) The yellow colors are due to an absorption starting in the ultra-violet and extending into the violet, which is attributable to the five-valent vanadium ion.

(2) Excess of V^{5+} extends the absorption band to include some blue, and the yellow deepens to amber.

(3) The green color is caused by absorption bands of trivalent vanadium ion, with a minimum absorption or maximum transmission around 525 mμ.

(4) The gray obtained with glasses high in boric oxide is caused by the insolubility of V_2O_5 in this solvent.

(5) Excess of alkali, as with the sodium metasilicate, favors the formation of the colorless vanadate ion.

The most striking fact about these findings is the great importance of basicity or acidity on the equilibrium color. Acid glasses favor the more basic state of vanadium, *i.e.*, the lower valence, trivalent vanadium ion. As the acidity is decreased by additions of alkali, pentavalent vanadium ion is favored, and the vanadium is finally converted entirely to the colorless vanadate.

So sensitive is this color change that it may be used to indicate the acidity of glasses and to compare the relative strengths of acid and basic constituents. For example, it brings out the strong acidity of P_2O_5, compared to SiO_2 and B_2O_3. If the glass contains divalent ions in sufficient amounts, the relative color intensity and changes upon decreasing the ratio of acid to alkali are not so pronounced.

The findings of the present writers are in agreement with the results of Fuwa,[1] as far as the influence of oxidizing and reducing conditions is concerned. His statement that the addition of boric oxide favors the coloration is interpreted to mean that by increasing the proportion of acid constituents the colorless portion of the vanadium (vanadates) is changed to the yellow polyvanadates and the green trivalent vanadium.

The present authors apparently have not been able to retain any quadrivalent vanadium in the glasses in their experiments. Divalent vanadium has such a strong tendency to oxidize that it could not be retained with the most extreme reducing conditions. Its analog, divalent chromium, which may be retained in a highly reduced glass, gives a bluish color. To obtain the lavender of bivalent vanadium a roundabout technique, based on an observation by Loeffler,[4] was used.

IV. Obtaining Bivalent Vanadium

When a glass is prepared with small amounts of vanadium and cerium, a green color is obtained owing to the V^{3+}. Cerium dioxide, introduced into a glass, is known to give off oxygen and to form the trivalent oxide. At low temperatures, this trivalent cerium shows a strong tendency to go back to its original tetravalent state. In the presence of trivalent vanadium, the following reaction seems to take place:

$$Ce^{+++} + V^{+++} \longrightarrow Ce^{++}_{++} + V^{++}.$$

Such a reaction requires a rather high activation energy and will not take place under ordinary conditions. In the presence of ultra-violet light, however, the cerium absorbs ultra-violet light quanta and goes into an activated state from which the reaction mentioned previously may be brought about. This is a special case of "solarization," *viz.*, a discoloring phenomenon under the influence of sunlight. In this case, the color change is from a faint green to pink. This process is now being developed for measuring ultra-violet intensities for climatological purposes.

In contrast with other solarization changes, such as the familiar development of a pink color in glasses which contain small amounts of iron and manganese, the cerium-vanadium reaction is very sensitive, and on a bright summer day a noticeable color change may be obtained in less than one hour with glasses having the proper proportions of cerium and vanadium.

Acknowledgment

The third author, A. E. Badger, wishes to express his thanks to W. Eitel, Director of the Kaiser Wilhelm Institut für Silikatforschung, for extending the use of the facilities of the Institute to him.

[4] H. Loeffler, unpublished communication.

EFFECT OF ALUMINA ON DEVITRIFICATION OF SODA-LIME-SILICA GLASSES*

By W. B. Silverman

Abstract

The effect of the substitution of Al_2O_3 for the oxides of sodium, calcium, and silicon on the liquidus temperatures and phase relations has been determined for glasses lying within the composition range Na_2O 11 to 19%, CaO 6 to 18%, SiO_2 59 to 79%, and Al_2O_3 0 to 8%. The results on 137 individual determinations show that the substitution of Al_2O_3 for CaO permits wollastonite to be the primary phase in glasses of relatively low CaO content. As the Al_2O_3 content increases, the $Na_2O{\cdot}3CaO{\cdot}6SiO_2$–$CaO{\cdot}SiO_2$ boundary shifts to lower CaO contents, and the decomposition of $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ to $CaO{\cdot}SiO_2$ takes place at lower temperatures. In compositions with tridymite as a primary phase, the substitution of Al_2O_3 for SiO_2 is effective in lowering the liquidus temperature. For the composition range investigated, the SiO_2–$CaO{\cdot}SiO_2$ and $Na_2O{\cdot}3CaO{\cdot}6SiO_2$–$SiO_2$ boundary remains at essentially the same SiO_2 content for all glasses containing not more than 4% Al_2O_3.

I. Introduction

The measurements presented in this paper are a part of the study of several properties in a portion of the Na_2O–CaO–Al_2O_3–SiO_2 system, which is (or will be) of value to the manufacturers of glass containers.

Alumina has played an important rôle for many years in the production of usable calcite glasses. The problem of producing a durable calcite glass that will not devitrify and yet will have the correct order of viscosity for machine fabrication has been solved by the use of either alumina or magnesia. The necessity of departing from glasses of the pure calcite type, *i.e.*, glasses containing only about 1/2% alumina plus magnesia, from the devitrification viewpoint is pointed out in the original work in that system. Morey and Bowen[1] have shown that 15% Na_2O is the lowest alkali content that can be used in the system to produce a glass with a liquidus temperature of less than 1830°F.

This paper covers only a limited portion of the quaternary system in short detailed steps. The liquidus temperatures of many of the glasses in the interior of areas are presented, and no attempt has been made to follow boundary lines out of the field being studied.

Morey[2] has already presented ample proof that alumina glasses have decidedly better devitrification characteristics than nonaluminous glasses. He has also pointed out that general conclusions should not be attempted from the limited amount of data he has presented.

Müllensiefen and Zschimmer[3] have covered part of the field presented here in their study of the rate of growth of crystals. A comparison with their data is presented later.

II. Method

The method used in this work is not as well known as the quenching method developed by the Geophysical Laboratory, but it presents some advantages from the commercial viewpoint of devitrification insofar as the devitrification conduct can be followed below the liquidus temperature in a single experiment.

If a cylinder of homogeneous glass is placed in a furnace with a gradient extending from above the liquidus temperature of the glass to one somewhere below that, the glass, when kept under these conditions a sufficiently long time, comes to equilibrium and precipitates the excessive solids consistent with the equilibrium conditions for the particular temperature. This process is carried out in a horizontal platinum-wound furnace which has a temperature gradient of approximately 100°F per inch. The specimen is made of finely powdered glass, previously melted in platinum and chemically analyzed. About 7 grams of the powder are distributed over the bottom of a Pt-Rh boat, so that when the powder is melted and fined a layer about 1/16 inch deep is formed at the bottom of the boat. The boats are 8 1/2 by 1/2 by 3/8 inch; the sides and bottom are flat.

After the devitrification has been carried out, a traverse of the furnace is made with a probing thermocouple to determine the temperature gradient. The measurements are made at 1/2-inch intervals along the length of the boat; the temperature between any two successive points is considered to vary linearly.

The boat is removed from the furnace and cooled in air until the temperature has fallen below red heat; a pair of tongs is inserted within the boat, and the sides are pushed out until the glass tears from the walls. A gentle tap on the bottom of the boat is sufficient to remove the devitrified specimen in a single "thin" section.

The thin section is then examined under a microscope for the point at which devitrification ceases. The crystalline product, in most cases, has been identified in

* Presented at the Forty-First Annual Meeting, American Ceramic Society, Chicago, Ill., April 18, 1939 (Glass Division). Received April 18, 1939.

[1] G. W. Morey and N. L. Bowen, "Ternary System Sodium Metasilicate–Calcium Metasilicate–Silica," *Jour. Soc. Glass Tech.*, **9** [35] 226–64 (1925); *Ceram. Abs.*, **5** [2] 63 (1926).

[2] G. W. Morey, "Effect of Alumina on Devitrification of a Soda–Lime–Silica Glass," *Jour. Amer. Ceram. Soc.*, **13** [10] 718–24 (1930).

[3] W. Müllensiefen and E. Zschimmer, "Influence of Alumina on Constants of Devitrification of Soda-Lime-Silicate Glasses," *Glastech. Ber.*, **9** [5] 280–307 (1931); *Ceram. Abs.*, **11** [7] 405 (1932).

section, but oil-immersion methods were used in doubtful instances and extensively at the start of the investigation.

Figure 11 is a schematic drawing of the furnace used in this work.

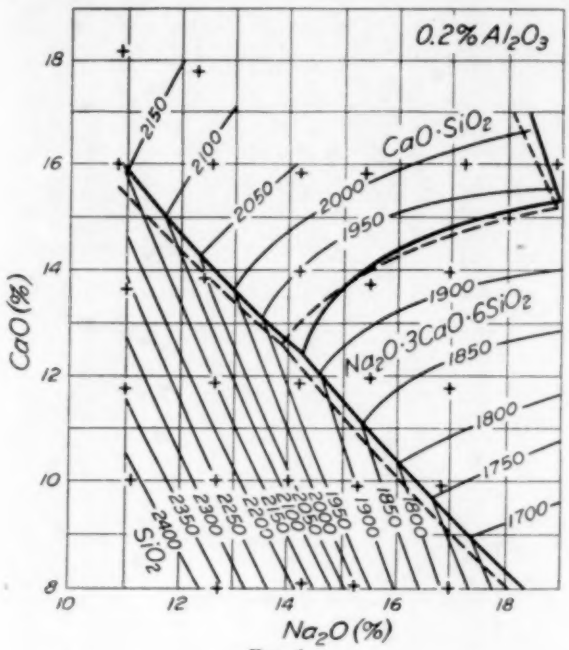

FIG. 1.

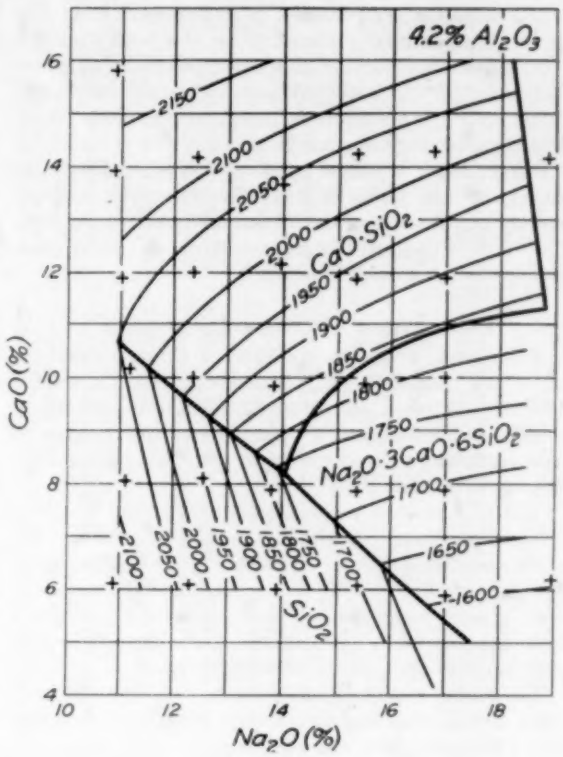

FIG. 3.

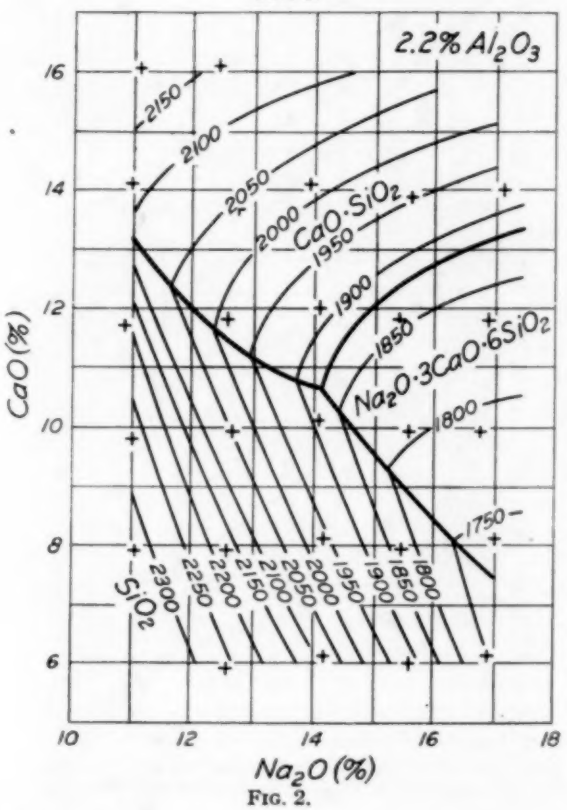

FIG. 2.

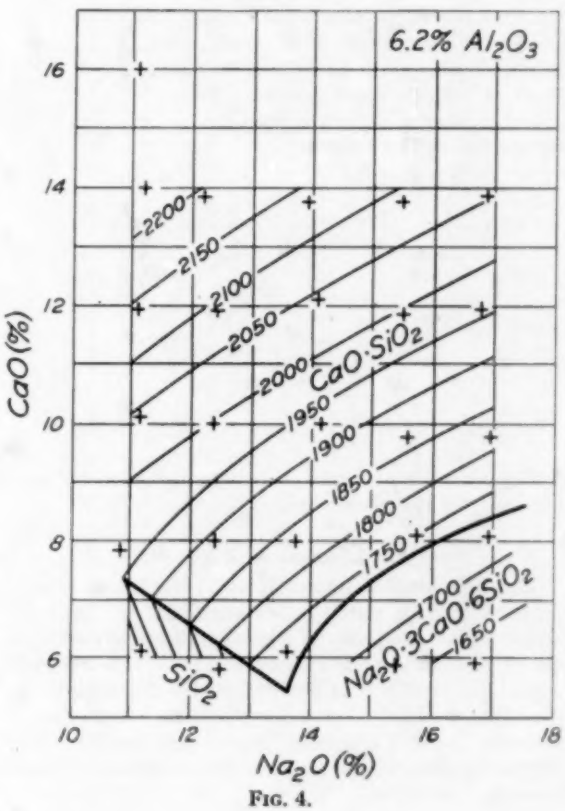

FIG. 4.

The liquidus temperature is determined from the known temperature gradient along the boat and the point at which crystallization ceases when equilibrium is established. The over-all accuracy of the method is about 15°F. This figure is based on numerous check determinations of the same glass.

Homogeneity is judged by sharpness of the line separating the true liquid from the liquid-crystal mixture and by the absence of devitrified spots above the line. The "line" will always be very narrow, and a variation of more than 0.05 inch is unusual.

III. System of Glasses Investigated

The glasses of this series have been made from the usual raw materials, *viz.*, Ottawa sand, St. Genevieve calcite, soda ash, aluminum hydroxide, and ammonium sulfate. (The amount of ammonium sulfate present was small but sufficient to give approximately 0.20% SO_3 in the finished glass.)

The glasses were melted in 4- to 5-pound lots in a covered platinum crucible in a gas-fired furnace. The glass was stirred several times during the melting process with an alloy stirring rod. Several of the more viscous glasses were crushed and remelted to obtain a homogeneous melt. Fragments of the large melt were powdered for the liquidus determination.

All glasses were analyzed; those which varied more than certain specified limits were discarded, and new melts were prepared and analyzed.

The glasses of the series were divided into several groups containing 0.2, 2.2, 4.2, 6.2, and 8.2% Al_2O_3. The soda content in each of the groups varied from 11 to 17% in 1.5% steps; the lime from 6 to 16% in 2% steps. Several glasses were made outside this range at 19% Na_2O, at 18% CaO, and one at 4% CaO.

The number of glasses at each Na_2O, CaO, and Al_2O_3 content is listed in Table I.

TABLE I

Al_2O_3 content (%)	No. of glasses	Na_2O content (%)	No. of glasses	CaO content (%)	No. of glasses
0.2	28	19	6	18	2
2.2	26	17	26	16	11
4.2	29	15.5	25	14	27
6.2	26	14.0	25	12	25
8.2	28	12.5	27	10	25
		11.0	28	8	25
				6	21
				4	1

The complete analyses as well as the liquidus temperatures of the glasses are given in Table II.

IV. Discussion of Results

The individual determinations of the liquidus temperature and primary phases are listed in Table II. The liquidus isotherms of Figs. 1 to 9 are drawn from the original data; the crosses on Figs. 1 to 5 represent actual compositions as determined by chemical analysis. The occasional cross for which no composition is listed in Table II represents glasses obtained by blending two glasses for the more accurate determination of boundary positions.

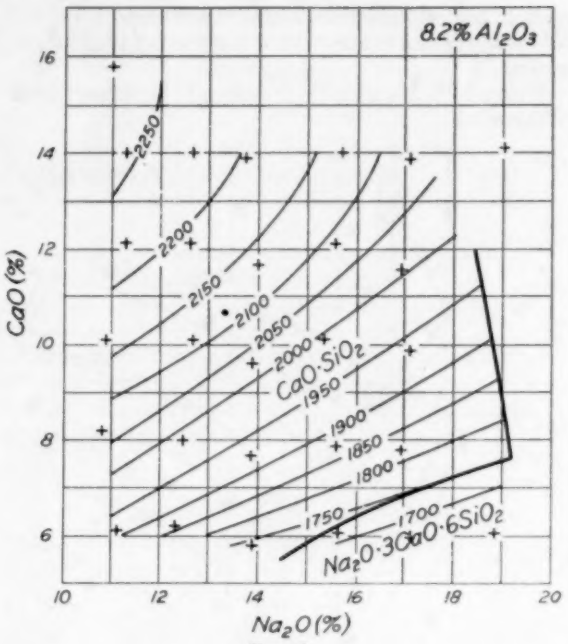

FIG. 5.

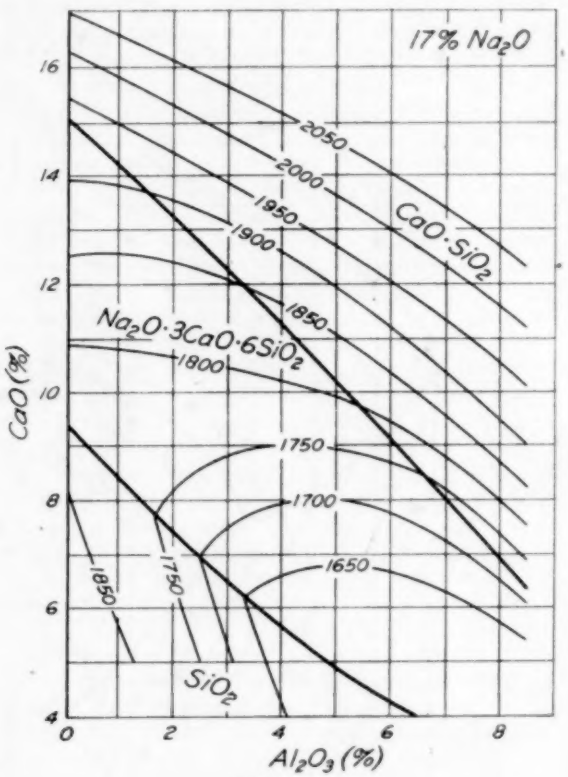

FIG. 6.

Figures 1 to 5 represent parallel planes in the quaternary system at different alumina contents. Each of these planes is parallel to the Na_2O–CaO–SiO_2 face of the tetrahedron. Figures 6 to 10 represent planes

TABLE II*

No.	SiO_2 (%)	R_2O_3 (%)	CaO (%)	MgO (%)	Na_2O (%)	SO_3 (%)	Total	Liquidus temp. (°F)	Phase
1	72.3	0.3	8.0	0.1	19.0	0.2	99.9	1625	Dev.
2	64.5	0.2	15.8	0.2	18.9	"	99.8	2005	1:2:3
3	70.7	4.0	6.0	0.1	"	"	99.9	1605	Dev.
4	62.6	4.1	13.9	0.2	"	"	"	1985	1:2:3
5	66.8	8.0	6.0	0.1	"	"	100.0	1645	Dev.
6	58.6	8.1	13.9	0.2	19.0	"	"	2050	1:2:3
7	74.4	0.2	7.9	"	17.0		99.7	1795	T
8	72.5	"	9.8	"	16.9	0.3	99.9	1735	Dev.
9	70.7	"	11.7	0.1	17.0	"	100.0	1840	"
10	68.6	"	13.8	0.2	17.0	"	100.1	1905	"
11	66.4	0.1	15.8	0.2	17.2	0.2	99.9	1985	W
12	74.8	2.2	6.0	0.1	16.9	"	100.2	1740	T
13	72.6	2.1	8.0	"	17.1	"	100.1	1750	Dev.
14	71.0	"	9.8	"	16.8	"	"	1790	"
15	69.1	"	11.7	"	16.9	"	"	1835	"
16	66.6	2.0	13.7	0.2	17.2	0.3	100.0	1960	W
17	75.0	4.1	3.9	0.1	16.9	0.2	100.2	1645	T
18	72.9	4.1	5.8	"	17.0	"	100.1	1600	Dev.
19	71.0	4.2	7.8	"	"	"	100.3	1690	"
20	68.9	4.1	9.9	"	"	"	100.2	1795	"
21	66.8	4.2	11.8	"	"	"	100.1	1905	W
22	64.5	4.2	14.2	"	16.8	"	100.0	2030	W
23	70.7	6.2	6.0	"	16.8	0.3	100.1	1625	Dev.
24	68.8	6.1	7.8	0.3	17.0	0.3	100.3	1730	"
25	66.7	"	9.6	0.2	17.0	0.4	100.0	1830	W
26	65.0	"	11.7	0.3	16.8	0.3	100.2	1985	"
27	62.7	6.2	13.9	0.1	17.0	0.2	100.1	2055	"
28	68.5	8.1	5.9	0.1	17.1	0.3	100.0	1690	Dev.
29	66.9	"	7.6	0.2	16.9	0.3	"	1805	W
30	64.8	"	9.7	"	17.1	0.2	100.1	1930	"
31	62.8	"	11.4	"	17.0	"	99.7	2000	"
32	60.7	"	13.5	"	17.1	"	99.8	2065	"
33	76.3	0.1	7.8	"	15.3	"	99.9	1995	T
34	74.2	0.2	9.8	"	15.4	0.1	"	1895	"
35	72.3	0.1	11.8	"	15.5	0.2	100.1	1845	Dev.
36	70.3	0.2	13.6	"	"	"	100.0	1910	"
37	68.3	0.2	15.7	"	"	"	100.1	1995	W
38	76.3	2.1	5.9	0.1	15.6	"	100.2	1940	T
39	74.5	"	7.8	"	15.5	"	"	1840	"
40	72.2	"	9.8	"	15.6	"	100.0	1770	Dev.
41	70.5	2.2	11.7	"	15.4	"	100.1	1855	"
42	68.2	2.1	13.7	0.2	15.6	"	100.0	1985	W
43	74.5	4.1	6.0	0.1	15.4	"	100.3	1735	T
44	72.6	4.1	7.8	"	15.4	"	100.2	1725	Dev.
45	70.4	4.2	9.8	"	15.5	"	"	1815	"
46	68.5	"	11.7	"	15.4	"	100.1	1940	W
47	66.1	"	14.2	"	15.4	"	100.2	2050	"
48	72.0	6.2	5.9	"	15.5	0.3	100.0	1705	Dev.
49	70.0	6.1	8.0	0.2	15.6	"	100.2	1825	W
50	68.2	"	9.6	0.2	15.6	"	100.0	1895	"
51	66.1	"	11.6	0.3	15.5	"	99.9	2000	"
52	64.5	6.0	13.6	0.2	15.5	0.1	"	2075	"
53	70.0	8.0	6.0	0.1	15.7	0.1	"	1705	Dev.
54	68.0	8.1	7.7	0.2	15.7	0.3	100.0	1840	W
55	66.3	"	10.0	0.1	15.4	0.2	100.1	1975	"
56	64.0	"	11.9	0.2	15.6	"	100.0	2095	"
57	62.2	8.0	13.8	"	15.7	"	100.1	2100	"
58	77.4	0.2	7.9	"	14.3	"	100.2	2190	T
59	75.7	"	10.0	0.1	14.0	"	"	2110	"
60	73.7	"	11.8	"	14.2	0.1	100.1	1920	"
61	71.6	"	13.9	"	14.2	0.1	"	1920	W
62	69.5	"	15.7	0.2	14.1	0.2	99.9	2085	"
63	77.5	2.1	6.0	0.1	14.2	"	100.1	2105	T
64	75.6	2.2	7.9	"	14.2	"	100.2	1965	"
65	73.5	"	10.0	"	14.1	"	100.1	1860	"
66	71.7	"	11.8	0.2	14.1	"	100.2	1915	W
67	69.7	"	13.9	0.2	14.0	"	"	1995	"
68	75.9	4.2	5.9	0.1	13.9	"	"	1905	T
69	74.1	4.1	7.7	0.2	13.8	0.2	100.1	1795	T
70	72.1	4.1	9.7	0.1	13.9	"	"	1885	W
71	69.4	4.2	12.0	0.2	14.0	0.3	"	1975	"
72	67.9	4.2	13.7	0.1	14.0	0.2	"	2075	"
73	73.8	6.1	6.1	"	13.7	"	100.0	1725	"
74	72.0	6.0	7.9	"	13.8	"	"	1840	"
75	69.8	6.0	9.9	"	14.1	"	100.1	1950	"
76	67.4	6.1	12.1	"	14.1	"	100.0	2050	"
77	65.7	6.1	13.8	"	14.0	"	99.9	2155	"
78	71.9	8.3	5.7	"	13.9	"	100.1	1760	"
79	70.0	8.3	7.6	"	"	"	"	1915	"
80	67.8	8.2	9.6	"	"	"	99.8	2020	"
81	65.8	8.1	11.6	"	14.0	"	99.8	2145	"
82	63.4	8.2	13.7	0.2	14.3	"	100.0	2210	"
83	78.8	0.2	7.9	0.1	12.7	"	99.9	2370	T
84	77.0	"	9.9	"	"	"	"	2235	"
85	75.0	"	11.8	"	"	0.2	100.0	2185	"
86	73.3	"	13.8	"	12.5	"	100.1	2020	W
87	71.2	"	15.9	"	12.6	"	100.2	2075	"
88	69.7	"	17.6	0.2	12.3	"	"	2140	"
89	78.8	2.1	5.8	0.1	18.6	"	99.6	2265	T
90	76.8	2.1	7.8	"	12.6	"	"	2190	"
91	75.2	2.2	9.8	"	12.7		100.0	2040	"
92	73.1	2.2	11.7	"	12.6		99.7	1960	W
93	71.2	2.0	13.6	"	12.8	0.2	99.9	2030	"
94	69.3	2.1	15.9	0.2	12.4	0.2	100.1	2145	"
95	77.3	4.1	5.9	0.2	12.3	0.3	"	2020	T
96	75.0	4.3	8.0	0.1	12.6	0.2	100.2	1970	"
97	73.2	4.2	9.7	0.3	12.4	0.3	100.1	1960	W
98	71.2	"	11.7	"	"	"	"	2040	"
99	68.9	"	14.0	"	"	"	"	2130	"
100	75.2	6.2	5.6	0.2	12.6	0.2	100.0	1830	"
101	73.2	6.0	7.9	0.1	12.5	"	99.9	1875	"
102	71.3	6.1	9.9	0.1	12.4	"	100.0	2000	"
103	69.2	6.1	11.8	0.2	12.5	"	"	2100	"
104	67.5	6.3	13.8	0.1	12.3	"	100.2	2200	"
105	73.5	8.0	6.1	0.1	12.3	0.1	100.1	1830	"
106	70.9	8.1	7.9	0.2	12.7	"	99.9	1985	"
107	68.9	8.0	10.0	0.1	12.7	"	99.8	2100	"
108	67.1	8.1	11.9	0.2	12.6	0.2	100.0	2185	"
109	65.0	8.0	13.8	0.2	12.7	"	99.9	2210	"
110	78.8	0.2	9.9	0.1	11.1	"	100.3	2425	T
111	77.0	"	11.7	"	11.0	"	100.2	2330	"
112	75.0	"	13.6	"	11.0	"	100.1	2290	"
113	72.7	0.3	15.8	0.2	10.8	"	100.0	2165	"
114	70.7	0.2	18.0	0.2	10.9	"	100.2	2185	W
115	78.7	2.2	7.8	0.1	11.1	"	100.1	2310	T
116	76.9	2.2	9.7	0.1	11.0	"	"	2290	"
117	75.1	2.1	11.5	0.2	10.9	0.3	"	2200	"
118	72.8	2.2	13.9	0.2	11.0	0.2	100.3	2110	W
119	70.3	2.3	16.0	0.1	11.1	0.2	100.0	2190	"
120	78.9	4.2	5.9	0.2	10.8	0.3	100.3	2140	T
121	76.5	4.2	7.8	"	11.1	0.2	100.0	2075	"
122	74.2	4.3	10.0	"	11.2	0.3	100.2	2040	"
123	72.9	4.1	11.7	"	11.0	0.3	"	2075	W
124	70.6	4.2	13.6	0.3	10.8	0.4	99.9	2120	"
125	68.9	4.2	15.5	0.3	10.9	0.4	100.2	2185	"
126	76.4	6.0	6.0	0.2	11.3	0.2	100.1	1985	T
127	75.0	6.0	7.6	0.2	10.9	0.3	100.0	1960	W
128	72.1	6.2	9.8	0.3	11.2	0.3	99.9	2050	"
129	70.7	6.1	11.8	0.1	11.1	0.2	100.0	2190	"
130	68.3	6.1	13.9	"	11.3	"	99.9	2235	"
131	66.4	6.2	15.9	"	11.2	"	100.0	2220	"
132	74.7	8.0	6.0	"	11.1	0.1	"	1920	"
133	73.0	8.2	8.1	"	10.8	"	100.3	2065	"
134	70.9	8.2	10.0	"	10.9	"	100.2	2165	"
135	68.4	8.1	11.9	0.2	11.3	"	100.0	2210	"
136	66.4	8.1	13.8	"	11.3	0.2	"	2255	"
137	64.7	8.4	15.6	"	11.0	0.2	100.1	2265	"

* The author wishes to acknowledge the contributions of Paul Close and J. C. Coleman to this work; Mr. Close for the analytical work, and Mr. Coleman for the preparation of the glasses.

parallel to the CaO–Al_2O_3–SiO_2 face at different soda contents.

Figure 1 compares the position of the boundary lines of Morey and Bowen (broken lines) and those determined in this work (solid lines); the silica-devitrite and the silica-wollastonite boundaries are about 1/2% silica apart; the wollastonite-devitrite boundaries are closer. The quintuple points, as drawn, vary by about 0.7% Na_2O. Considering the small amount of MgO and SO_3 in this series, the boundary lines check well.

Figures 1 to 3 indicate that the silica boundary remains close to 73.5% SiO_2. For glasses of this series containing more than 4% Al_2O_3, the boundary shifts toward higher SiO_2 content.

The field of $Na_2O{\cdot}3CaO{\cdot}6SiO_2$ is materially less as Al_2O_3 increases, whereas the field of wollastonite is expanded greatly and becomes the primary phase for glasses of much lower CaO content than for the original system (low alumina glasses). The temperature of the devitrite-wollastonite decomposition is continually lowered by the addition of alumina.

Figure 10 indicates the position of the boundaries at different alumina contents. The Na_2O content of the quintuple point remains essentially the same up to 4% Al_2O_3, then moves toward a lower soda content. The diminishing devitrite fields are well illustrated in this figure, and glasses containing 10% Al_2O_3 probably will not have devitrite as a primary phase.

The 1:2:3 compound was the primary phase only for three glasses of the series and occurred at high soda contents. The primary phase occurrence in the 0.2 Al_2O_3 series is consistent with the work of Morey and Bowen. The 1:2:3 compound is also a primary phase in glasses containing 6 and 8% Al_2O_3, but any discussion of the position of its field within the tetrahedron would only be speculative, based on the data presented here. The quintuple points wollastonite-devitrite-1:2:3 (Figs. 3, 5, and 10) may be off their real positions, but as they have been drawn their movement is toward a lower CaO content.

The decomposition of the 1:3:6 compound into wollastonite is shown in Fig. 12, a photomicrograph of glass No. 49 after 7 days in the furnace. The difference in the size of the wollastonite and devitrite crystals is notable. The coexistence of the two crystals over a temperature range is either impossible or extends over a small range. In no case have the two compounds appeared together below the inversion temperature.

TABLE III

	SiO_2	R_2O_3	CaO	Na_2O	M and Z	S	M and B
A_0	73.8	0.1	14.0	12.0	2085T	2110T	2085T
A_2	72.0	2.0	14.0	12.0	2100W	2080W	
A_4	67.9	6.1	14.0	12.0	2155W	2210W	
B_0	73.8	0.2	12.0	14.0	2055T	1940T	1920T
B_2	71.8	2.2	12.0	14.0	2165D	1920W	
B_4	69.7	4.3	12.0	14.0	2030D	1980W	
C_0	73.8	0.2	10.0	16.0	1995T	1820T	1785 Boundary composition
C_2	71.3	2.2	10.3	16.2	1850D	1810D	
C_4	69.4	4.1	10.3	16.2	1875D	1820D	
D_0	73.9	0.1	8.0	18.0	1870T	1690D	1670D
1	74.0	2.1	9.8	14.1		1900T	1825T
2	73.3	4.2	8.5	14.0		1770W	1840D
3	72.0	8.0	6.2	13.8		1760W	1885D

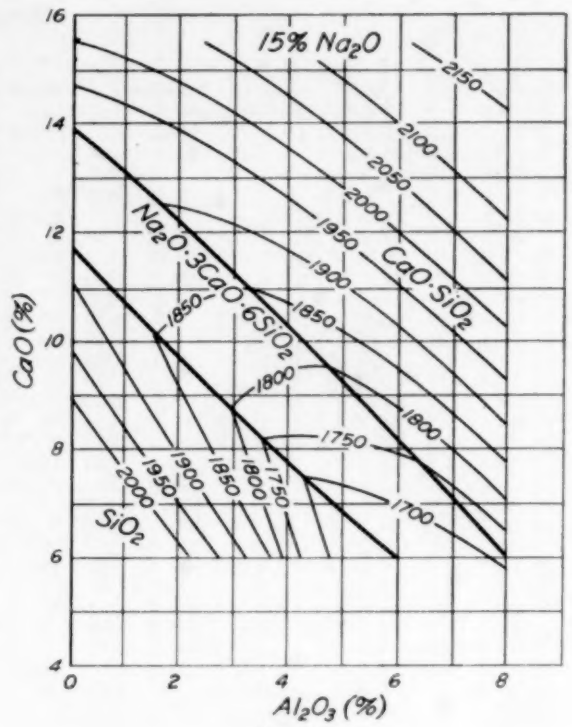

FIG. 7.

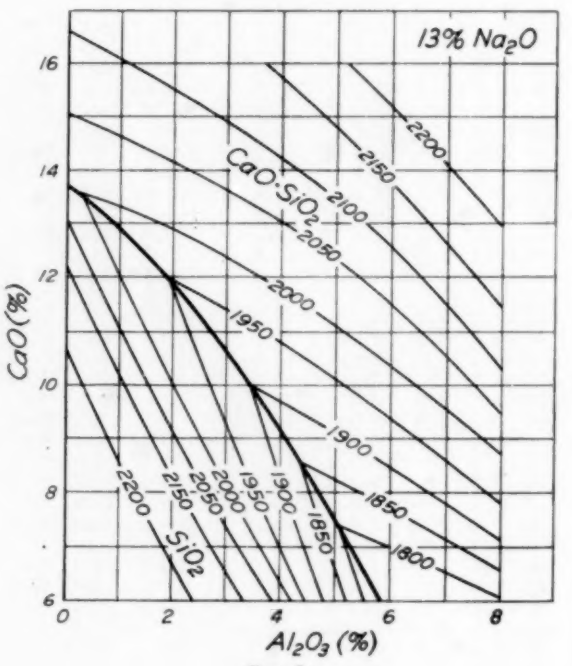

FIG. 8.

The available data on the devitrification of Na_2O–CaO–Al_2O_3–SiO_2 glasses are compared in Table III. The agreement of the present data and that of Morey and Bowen for glasses containing 0.2% alumina is fairly good considering the small amounts of impurities

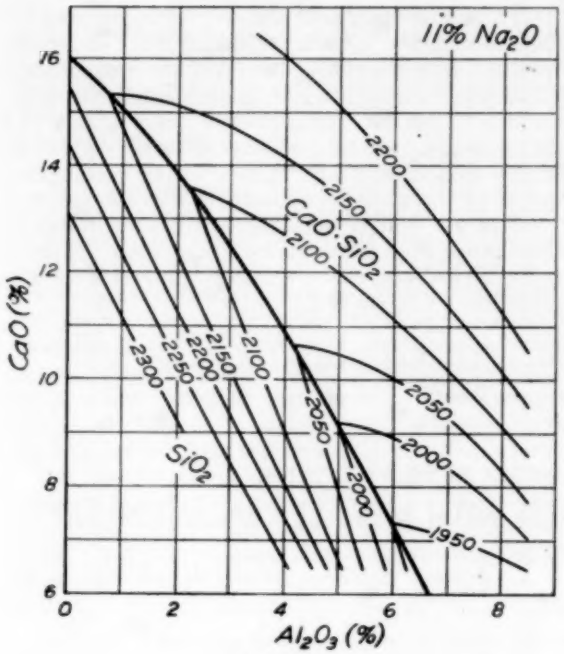

FIG. 9.

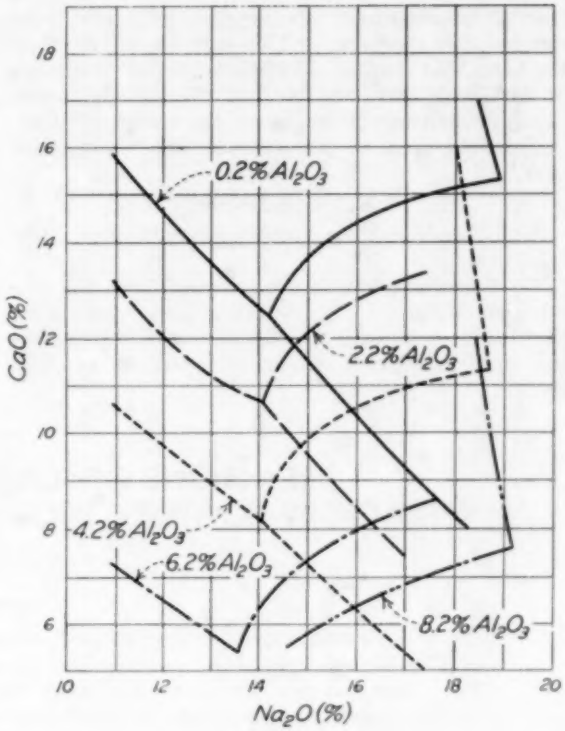

FIG. 10.

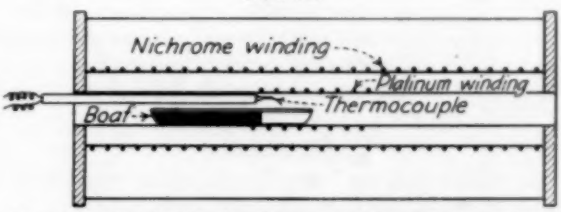

FIG. 11.—Devitrification furnace and method used to determine liquidus temperatures.

in the glasses. The Müllensiefen and Zschimmer temperatures are notably higher in these instances.

The agreement of the aluminous glasses of Morey with those of the series is not so good from the liquidus temperature standpoint. The difference in phases of the last two of Table III is not serious inasmuch as both glasses are near the boundary line. Glass No. 2 could easily have devitrite for the primary phase by changing the boundary a small amount, and this change would be consistent with the data (Fig. 3). The presence of SO_3 and MgO probably accounts for a part of the difference in liquidus temperature.

The primary phase of devitrite for glasses B_2 and B_4 does not seem to be correct, as the incongruent melting temperature of devitrite is less than 1950°F, and the present data indicate that the presence of alumina lowers the decomposition temperature. This is also indicated in Morey's work, which shows that at about 11% Al_2O_3 the boundary line lies close to the 1800°F isotherm.

The length of time to obtain equilibrium for these melts varies a great deal, from less than $^1/_2$ hour to 4 days. The time is always much longer than that reported by Morey, especially when the liquidus is low. This difference probably arises from the catalytic action of the platinum, for in many instances when equilibrium had not been reached, crystals could be observed along the sides and bottom of the boats, whereas the surface and interior were still undevitrified. This is especially true of the aluminous glasses of the devitrite field, which are the most difficult to bring to equilibrium. They display a rather odd conduct in coming to equilibrium. The glass in one day will show a heavy precipitation of crystals up to about 80°F below the liquidus. Further precipitation is slow, apparently due to the

FIG. 12.—Photomicrograph of decomposition of Na_2O·3CaO·6SiO_2 into CaO·SiO_2; magnification 70×.

lack of nuclei because the crystals will grow quite rapidly after they form. This may be explained on the basis that $Na_2O \cdot 3CaO \cdot 6SiO_2$ is highly dissociated in the liquid phase, and because it is the equilibrium phase at low temperatures where the viscosity is high, the rearrangement to form crystals takes considerable time.

V. Conclusions

A number of general conclusions may be drawn from this work.

(1) When tridymite is the primary phase, the substitution of Na_2O, Al_2O_3, or CaO for SiO_2 decreases the liquidus temperature. Alumina decreases the temperature more rapidly than calcium oxide but not as rapidly as soda.

(2) In the devitrite field, the effect of the alumina for silica substitution is quite variable, and the change in liquidus temperature in all cases is of minor importance if this substitution is made in glasses close to the silica-devitrite boundary. The initial tendency is to lower the liquidus temperature, whereas subsequent additions reverse this effect. The most effective composition change for this area is to decrease the CaO content.

(3) In the field of wollastonite, the substitution of alumina for silica increases the liquidus temperatures, and again the most effective change in lowering it is the reduction of CaO content.

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REACTIONS OF SLAG WITH REFRACTORIES II, REFRACTORY COATINGS PRODUCED WITH METALLIC ALUMINUM*

By H. G. Schurecht

Abstract

Hard refractory coatings with good adherence were produced on fire brick by spraying a slip composed of clay and aluminum powder on the samples and firing. Similar coatings were produced by spraying molten aluminum on fire brick. The hardness probably is produced by heat developed from aluminothermic reactions between the aluminum and clay, and the strong adherence is caused by similar reactions between the aluminum and fireclay brick. These reactions were found to start between 750° to 930°C, and the heat generated may raise the temperature of the coating up to 1500°C in five minutes. The coatings increased the resistance of fireclay refractories to attack from basic slags but caused acid slags to corrode them more than where no coatings were employed.

I. Introduction

According to Aram,[1] metallic aluminum may be applied to refractories, which after firing forms a refractory coating that offers protection of the refractory against the corrosion of slags. To apply the aluminum, Aram suggests spraying the refractories, dipping in the molten metal, or applying it electrolytically. The application of metal to refractories by these methods, however, is costly. Coatings composed entirely of metals, moreover, cannot be applied in thicknesses greater than 0.010 inch because they peel from the ware owing to an excessive expansion of the metal when they become oxidized.

A mixture of 10 parts of fire clay and 90 parts of aluminum powder gives satisfactory results for coatings up to 0.03 inch in thickness. For thicker coatings, it is necessary to increase the clay and grog contents to counteract the expansion produced by the oxidation of the aluminum powder.

The coatings produced with metallic aluminum were harder and possessed better adherence than those prepared with aluminum oxide owing to excessive exothermic heat which was developed between 750° and 930°C as a result of aluminothermic reactions between the aluminum metal and the clay. This reaction is similar to that obtained in the Goldschmidt thermit welding process except that in this case clay was used in place of iron oxide. The present thermit welding reactions may be written as follows:

$$8Al + 3Fe_3O_4 \longrightarrow 9Fe + 4Al_2O_3.$$

This reaction was calculated by Richards[2] to give a temperature of 2694°C (4881°F); using a radiation thermometer, M. Fery[3] found a stream of thermit molten metal to be 2300°C (4172°F).

II. Experimental Methods

Cylinders, 1 by 2 inches in size, were molded with holes 1/8 inch in diameter extending half way into the specimens. One thermocouple was inserted into the hole and another was introduced on the outside of the specimen in the furnace.

The resistance of coatings produced with aluminum metal to slag action was measured by the methods described in a previous report[4]; the same slags were also employed in the present work.

* Presented at the Fortieth Annual Meeting, American Ceramic Society, New Orleans, La., March 31, 1938 (Refractories Division). Received February 8, 1939.

[1] Otto Aram, U. S. Pat. 1,576,021, March 9, 1928.

[2] J. W. Richards, Metallurgical Calculations, pp. 58–60. McGraw-Hill Book Co., Inc., New York, N. Y., 1917.

[3] Etham Viall, Gas Torch and Thermit Welding, pp. 317–425. McGraw-Hill Book Co., Inc., New York, N. Y., 1921.

[4] H. G. Schurecht, "Reactions of Slags with Refractories: I, Surface Reactions," *Jour. Amer. Ceram. Soc.*, 22 [4] 116–23 (1939).

A wire of the metal was run through a gun into an oxyacetylene cone flame and sprayed on the refractory. A thickness of 0.010 inch was used because it was found that thicker coatings tended to peel off in subsequent firings owing to the high expansion of the aluminum in becoming oxidized.

A duplicate set of specimens was sprayed with a slip of 58 parts water, 10 Tennessee ball clay, and 90 aluminum powder. The screen analysis of powder was as follows: 100- to 150-mesh, 4.0%; 150- to 200-mesh, 6.0%; 200- to 325-mesh, 15%, and < 325-mesh, 75%.

The clay and aluminum powder were first mixed dry and the water was added. If allowed to stand longer than two hours, excessive heat was generated, evidently due to a chemical reaction between the aluminum powder and the other ingredients of the slip. An average thickness of 0.023 inch of slip was sprayed on the fired fireclay disks using a standard glaze spray gun.

Slag spheres were placed in the center of the disks on unfired coatings. They were then fired to different temperatures and measurements of the buttons were made, such as height, diameter, volume, visible penetration, calculated penetration, and angle of contact.

III. Results

The results of the exothermic effects produced between aluminum powder, clay, and grog upon heating

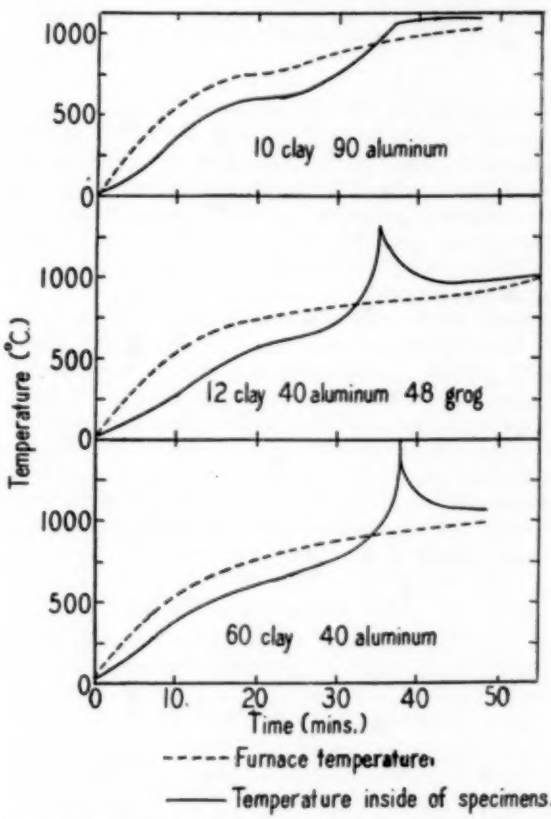

FIG. 1.—Thermal behavior of clay, grog, and aluminum mixtures.

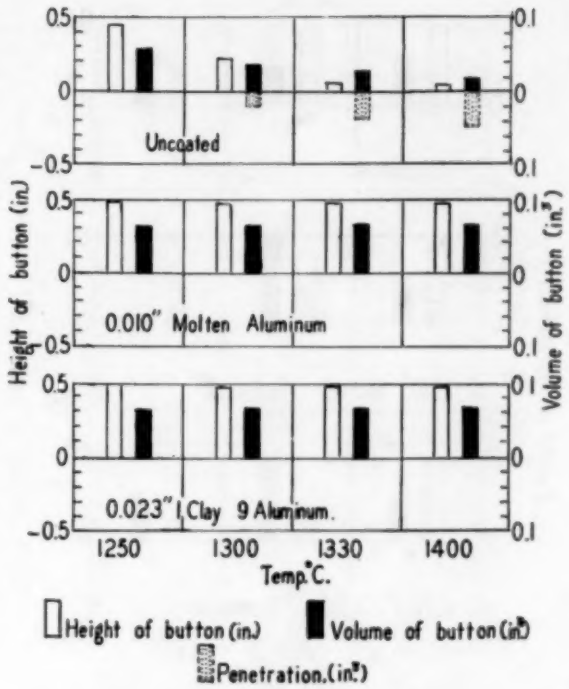

FIG. 2.—Effect of aluminum coatings on reactions of Portland cement clinker with fire clay.

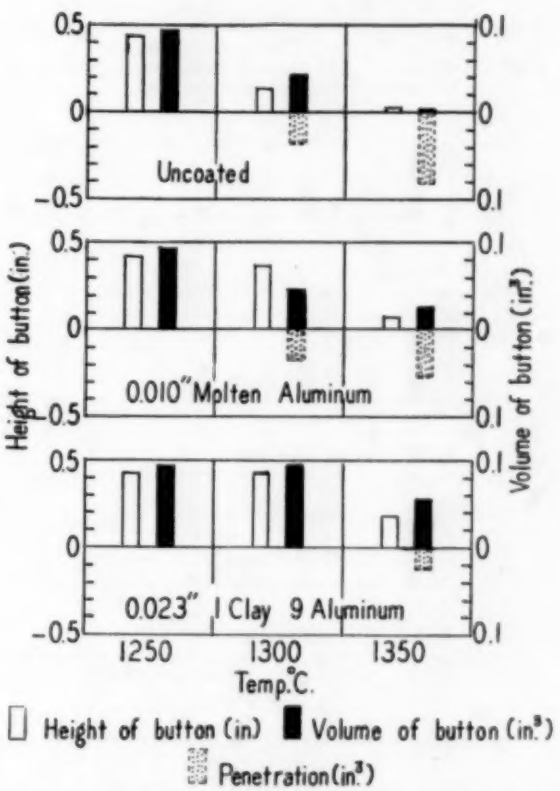

FIG. 3.—Effect of aluminum coatings on reactions of blast-furnace slag with fire clay.

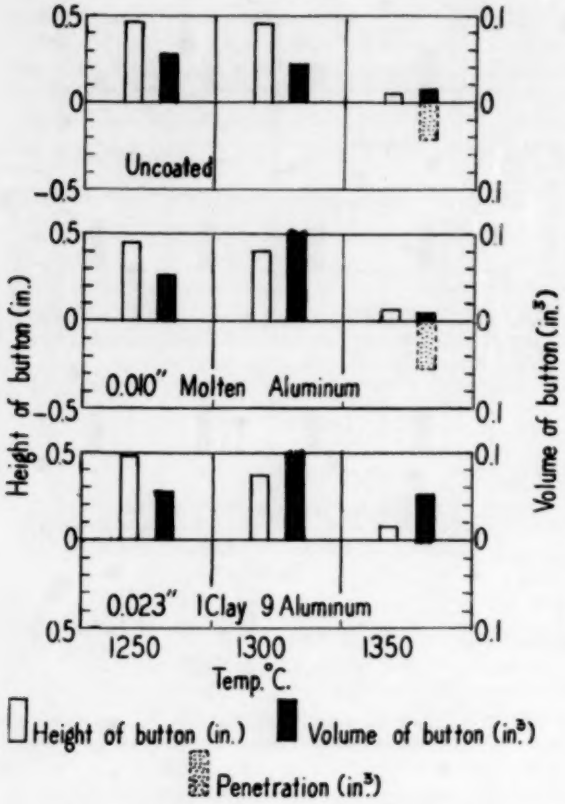

FIG. 4.—Effect of aluminum coatings on reactions of zinc-furnace slag with fire clay.

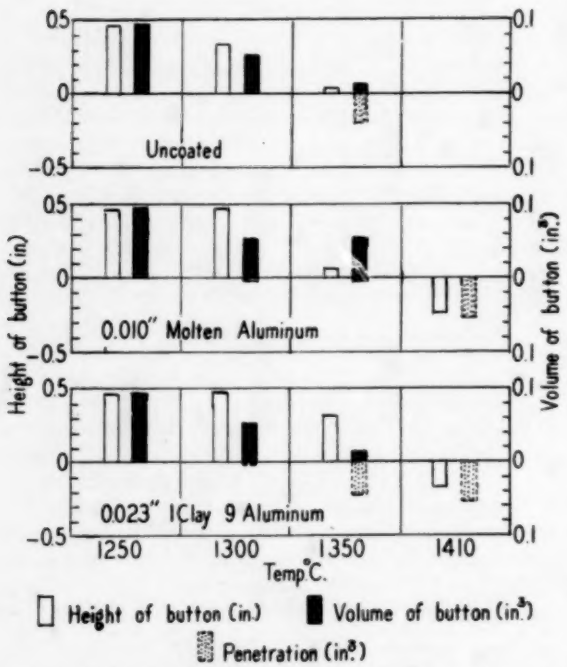

FIG. 5.—Effect of aluminum coatings on reactions of basic open-hearth slag with fire clay.

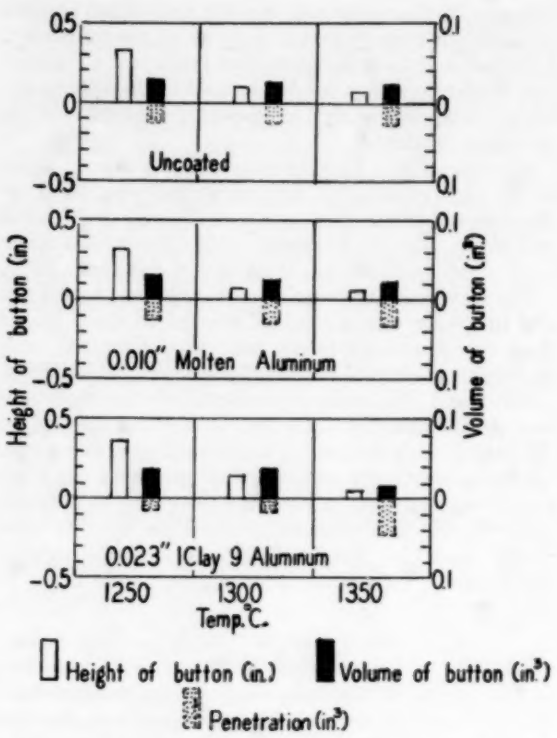

FIG. 6.—Effect of aluminum coatings on reactions of coal ash with fire clay.

are shown in Fig. 1. The reactions apparently start at temperatures between 750° and 930°C. The temperature reached in the interior of the specimens was much higher with 60% clay than it was with 10% clay. It was also much higher with 12% clay and 48% grog than it was with 10% clay. This is evidence that this reaction takes place between aluminum and fired clay as well as between aluminum and raw clay.

Some of the results of the slagging tests are shown in Figs. 2 to 10. It is evident that the coatings produced with metallic aluminum on fire clay improve their resistance to the corrosion of certain slags like Portland cement clinker and blast-furnace slag and that they increase the corrosion from lead-blast furnace slag and soda-lime glass. The coating composed of 1 clay and 9 aluminum powder in most cases produced a more protective coating than those obtained from the molten aluminum sprayed on the refractory.

IV. Discussion of Results

The heat developed when metallic aluminum was employed probably accounts for its greater hardness and adherence compared with the softer coatings obtained with aluminum oxide. From Fig. 1, it is evident that this reaction may take place with the fired clay refractory as well as with the raw clay. This reaction probably explains the superior bond obtained between these coatings and the fired clay refractories on which they are applied.

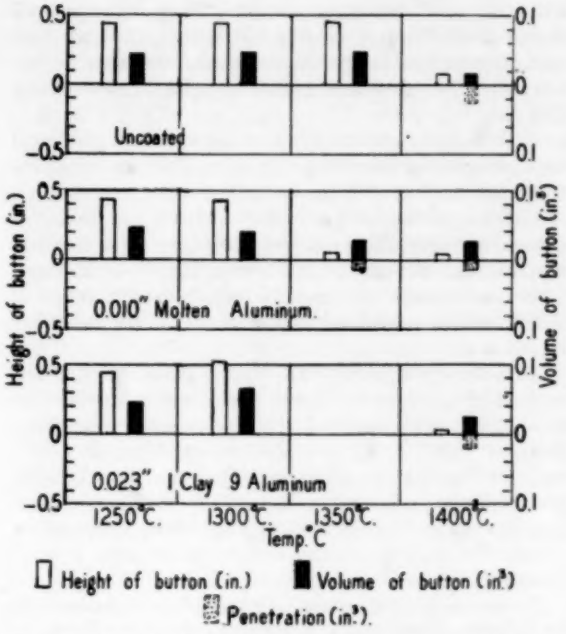

FIG. 7.—Effect of aluminum coatings on reactions of copper reverberatory slag with fire clay.

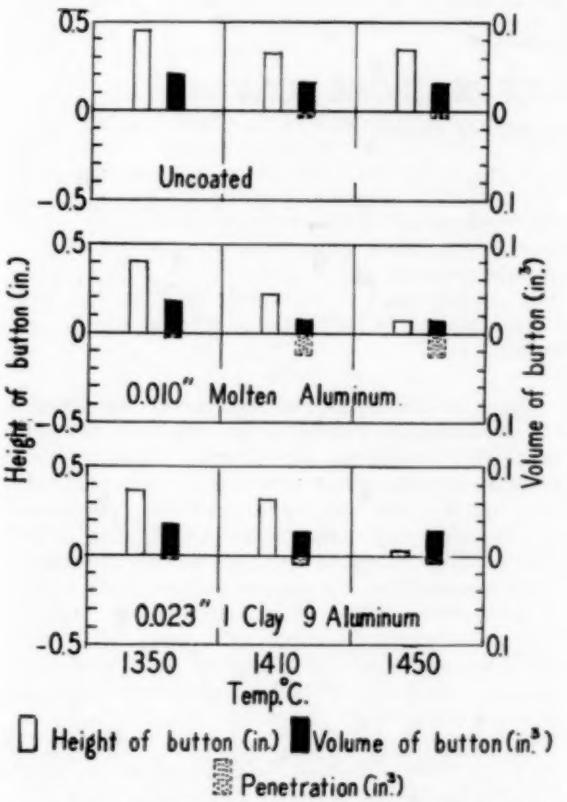

FIG. 8.—Effect of aluminum coatings on reactions of acid open-hearth slag with fire clay.

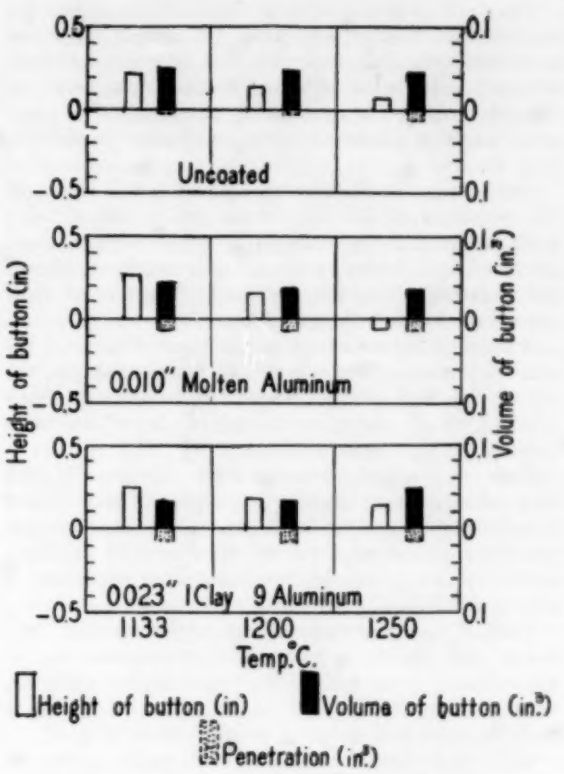

FIG. 9.—Effect of aluminum coatings on reactions of lead blast-furnace slag with fire clay.

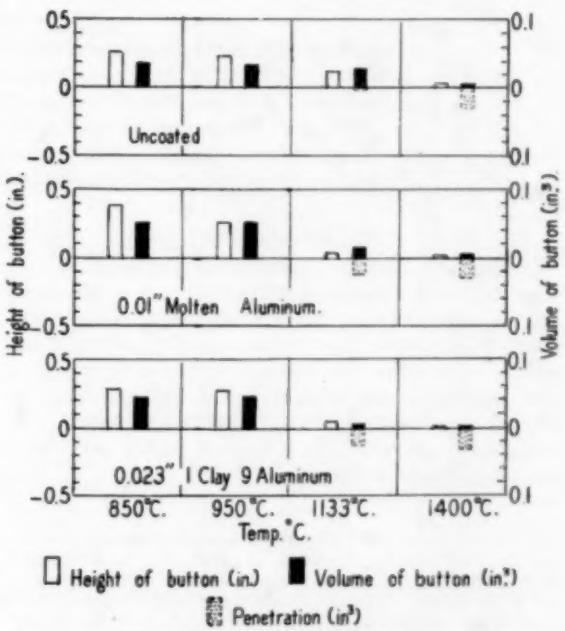

FIG. 10.—Effect of aluminum coatings on reactions of soda-lime glass with fire clay.

The coatings produced with aluminum improved the resistance of fireclay refractories to certain slags and decreased their resistance to others. Portland cement clinker reacted with uncoated fireclay refractories at temperatures as low as 1300°C, but it failed to react with coatings produced with aluminum at 1400°C (Fig. 2).

The coatings produced with aluminum also increased the resistance of fireclay refractories to the slagging action of blast-furnace slag. Of these coatings, those produced with a mixture of clay and aluminum offered the greatest protection, evidently because of their greater thickness (Fig. 3).

A coating apparently was produced with good resistance to the slagging action of zinc-furnace slag by the use of clay and aluminum powder, whereas that obtained from a spray of molten aluminum offered little or no protection to the refractory (Fig. 4).

These coatings also improved the resistance of fireclay refractories to the slagging action of basic open-hearth slag (Fig. 5). With coal ash, the clay and aluminum protected the fireclay refractories at 1250° and 1300°C, but apparently did not offer much protection at 1350°C (Fig. 6).

With copper reverberatory slag, the coatings produced with aluminum gave little or no protection to the refractory on which they were applied (Fig. 7), whereas with acid open-hearth slag these coatings made the refractory less resistant to slag attack (Fig. 8).

With lead blast-furnace slag, the coating produced with clay and aluminum powder offered slight protection to the refractory on which it was applied whereas that obtained from the molten metal spray made the refractory less resistant to the slagging action of this slag (Fig. 9).

With soda-lime glass, both of the coatings produced with aluminum caused the refractory to be less resistant to corrosion (Fig. 10).

The slag action of basic slags (with a low ratio) in general is reduced to a marked extent by these coatings whereas the reverse is true with highly acid slags. There are exceptions to this rule, however, some of which may be explained by differences in the fusibility of the slags.

A mixture composed of 48 clay, 20 aluminum powder, and 32 grog showed 0% fire shrinkage when fired to cone 8, but it showed −1.7% volume expansion when fired to 1000°C. It is apparent therefore that this mixture remains almost constant in volume upon being fired. Similar mixtures were used as refractory plaster coatings up to $^1/_2$ inch in thickness with good results.

Acknowledgment

The writer wishes to acknowledge his indebtedness to the Metallizing Engineering Company of New York for coöperation in spraying molten aluminum on some of the specimens. He also appreciates the assistance given to him by the staff of the Ceramic Experiment Station and of M. E. Holmes for helpful guidance in this work.

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THERMAL DISSOCIATION OF DIASPORE CLAY*

By Paul G. Herold and C. M. Dodd

Abstract

Diaspore clay, under conditions of equilibrium, forms corundum and gamma alumina at 400°C. The gamma alumina gradually changes to corundum at higher temperatures, part of which combines with free silica to form mullite at about 1150°. Between 400° and 750°, there is a gradual increase in the size of the corundum unit cell as determined by X-ray crystal analysis, which, upon continued heating at higher temperatures, gradually reduces to the true dimensions of corundum.

I. Introduction

Diaspore clay is found in commercial quantities only in a small area throughout the central part of Missouri. The deposits are laid down in solution cavities[1] or "sink holes" in sandstone-lined limestone of the Ordovician period. The sediments comprising the diaspore clays were deposited during Pennsylvanian time and, as such, are associated with flint clays, shales, and other coal-formation clays which were formed during periods of intense chemical weathering.

Since the introduction of high-alumina refractories, the use of diaspore clay has been accelerated until there is a large demand for the material. The theoretical chemical formula of diasporite is $Al_2O_3 \cdot H_2O$, containing 85% alumina and 15% combined water; commercial diaspore clay may analyze between 65% alumina[2] and that amount indicated by the theoretical formula. Large quantities of diaspore cannot be used in making refractory ware without precalcination at an extremely high temperature, inasmuch as it has a high initial shrinkage and continues to shrink[3] when it is subsequently heated to the same temperature or higher in repeated firings.

* Presented at the Forty-First Annual Meeting, American Ceramic Society, Chicago, Ill., April 19, 1939 (Refractories Division). Received April 19, 1939.

[1] V. T. Allen, "Mineral Composition and Origin of Missouri Flint and Diaspore Clays," *Missouri Geol. Survey and Water Resources, 68th Biennial Rept.*, Appendix 4, 24 pp. (1935); *Ceram. Abs.*, **17** [1] 40 (1938).

[2] H. S. McQueen, "Geologic Relations of Diaspore and Flint Fire Clays of Missouri," *Jour. Amer. Ceram. Soc.*, **12** [10] 687–97 (1929).

[3] S. M. Phelps, "Study of Shrinkage of Diaspore Clays: I," *ibid.*, **9** [10] 659–66 (1926).

The investigation of the changes taking place in a high-grade diaspore clay therefore was undertaken to obtain some basic information on its behavior to known conditions of temperature and time treatment.

In a review of the literature, it was found that diasporite, the pure mineral, crystallizes in the holohedral orthorhombic[4] system (D_{2h}^{16}) and has the following optical characteristics[5]: biaxial positive, $\alpha = 1.702$, $\gamma = 1.750$, and $\beta = 1.722$. The only work that deals with the action of heat on the mineralogical changes in diaspore is described by Hüttig,[6] who states that upon dehydration, diaspore changes into corundum while böhmite ($Al_2O_3 \cdot H_2O$ with a crystalline structure differing from diaspore) changes into γ alumina.

The aluminum oxides that may be produced by heating the alumina hydrates are (1) α alumina or corundum,[7] which is called the high-temperature form of alumina and generally is thought to form at around 1000° to 1200°; (2) β alumina, formed by fusing or heating alumina with small amounts of some salt of sodium or potassium, which does not produce a new form of alumina but a sodium or potassium aluminate; (3) γ alumina, which is a cubic crystal easily soluble in the ordinary mineral acids, and is known as the low-temperature form of alumina. The structures of all three of these varieties of alumina are well known and have been determined previously, which simplifies the process of identification. Gamma alumina, however, usually crystallizes poorly into crystals large enough to be identified either by X-ray diffraction or by petrographic methods so that its determination is largely a matter of chemical solution.

II. Raw Materials

The material used in this investigation is a commercial diaspore clay with the following chemical analysis: SiO_2 15.02, Al_2O_3 65.22, Fe_2O_3 1.36, CaO 0.52, MgO 0.30, TiO_2 2.50, K_2O 1.17, Na_2O 0.14, and ignition loss 13.49%.

The ultimate analysis shows that the material contains 63.4% diaspore, 8.4% SiO_2 as free quartz, and 28.38% clay; the remainder is divided between iron oxide and titanium oxide, with traces of some other compounds of Cr, Sr, etc.

III. Methods

The diaspore clay was ground in a ball mill to pass a 100-mesh sieve, molded with water, and formed into rods 1/8 inch in diameter by 2 inches long by packing the moist material in a glass tube and extruding with compressed air. These samples were dried to constant weight at 110°C, placed on end in a diaspore clay plaque, and introduced into the furnace which was held at the desired temperature for 100 hours. The samples were then removed, ground, and placed in a desiccator. Samples were fired for 100 hours at temperatures ranging from 100° to 1100°C at 50°C intervals. The heating was done in a Nichrome-wound resistance furnace which was controlled by a water rheostat and equipped with a recording galvanometer. Other samples were fired for six hours at temperatures ranging from 1200° to 1700°C at 100°C intervals. A standardized noble metal couple was used to measure the temperatures. The temperature was controlled to ±5°C up to 1100°C. Above 1100°C, the samples, supported on a revolving plaque to obviate variations in heat treatment, were heated in a Fulton-Courson granular carbon-resistance furnace. Temperatures were checked every five minutes or oftener with an optical pyrometer, and the desired temperatures were maintained to ±15°C.

The resulting heat-treated samples were examined with the petrographic microscope and by X-ray diffraction methods for mineral identity. X-ray pictures were taken, using the Debye powder method with Cu-radiation. The optical spectrograph was used to examine samples for relatively small amounts of foreign materials, such as iron, chromium, strontium, etc. This equipment is of the diffraction-grating type, the sample being completely vaporized in a carbon arc. Each sample was tested further for chemical solubility by digesting in 30 cc. of 1 to 1 HCl for 24 hours on a sand bath. The sample was then filtered through a weighed Gooch crucible, and the loss by solution was calculated.

Each sample was ground sufficiently fine for testing and was examined by one or more of the test methods already explained. The results are given in Table I.

TABLE I

SOLUBILITY OF DIASPORE AT DIFFERENT TEMPERATURES

Heat treatment (temp.°C)	(hr.)	Crystalline phases present	(1)	(2)
110	100	Diaspore, clay, quartz	6.08	
150	"	" " "	6.90	
200	"	" " "	8.76	
250	"	" " "	8.80	
300	"	" " "	9.00	
350	"	" " "	9.08	
400	"	Corundum, γ-alumina	18.24	0.77
450	"	" " "	18.31	0.65
500	"	" " "	19.06	
550	"	" " "	20.43	0.43
600	"	" " "	20.03	
650	"	" " "	19.25	1.89
700	"	" " "	19.02	
750	"	" " "	18.64	2.06
800	"	" " "	14.87	
850	"	" " "	12.01	1.66
900	"	" " "	6.29	1.60
950	"	Corundum	1.94	0.36
1000	"	"	1.96	
1050	"	Corundum, mullite	1.96	
1100	6	" "	2.02	
1200	"	" "	3.90	0.41
1300	"	" "	3.95	0.55
1400	"	" "	4.21	0.30
1500	"	" "	3.28	0.59
1600	"	" "	3.94	0.36
1700	"	" "	3.03	0.30

Column (1), percentage soluble in 1 to 1 HCl; column (2), average percentage of corundum structure expanded.

[4] M. Deflandre, "Crystal Structure of Diaspore," *Bull. soc. franç. minéral.*, **55**, 140–65 (1932); *Ceram. Abs.*, **13** [10] 272 (1934).

[5] E. S. Larsen and H. Berman, "Microscopic Determination of Nonopaque Minerals," *U. S. Geol. Surv. Bull.*, No. 848, p. 131 (1934); *Ceram. Abs.*, **13** [7] 196 (1934).

[6] G. E. Hüttig and O. Kostelitz, "Beiträge zur Kenntnis der Oxydhydrate: XX, Das System Aluminiumoxyd-Wasser," *Z. anorg. allgem. Chem.*, **187** [1] 1–15 (1930); *Ceram. Abs.*, **9** [7] 579 (1930).

[7] J. D. Edwards and M. Tosterud, "Oxides and Hydrates of Aluminum," *Jour. Phys. Chem.*, **37** [4] 483–88 (1933); *Ceram. Abs.*, **12** [8] 308 (1933).

The data on the solubilities of the various diaspore samples are illustrated in Fig. 1.

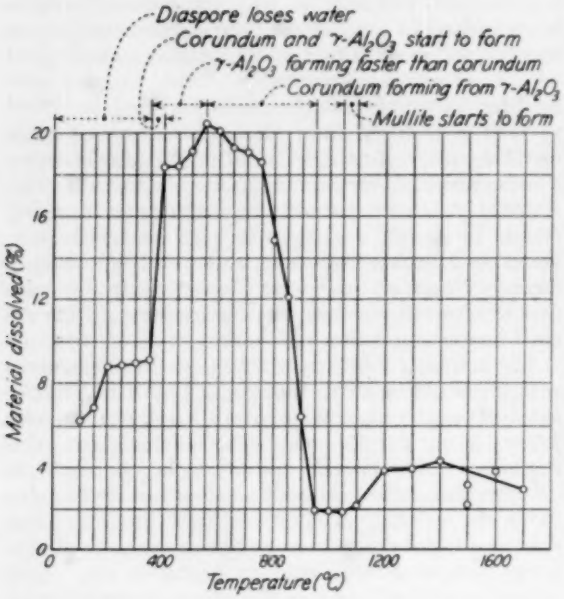

FIG. 1.—Solubility of diaspore at different temperatures.

IV. Discussion of Results

The diaspore samples were heated for 100 hours at temperatures lower than 1100°C to bring about a condition of equilibrium throughout the mass between the various minerals developed. To determine the speed of reaction of the formation of γ alumina and corundum at the 400°C transformation point, the temperature was held constant at 400, 450, and 500°C for various time intervals. It was found that both γ alumina and α alumina form as soon as the sample reaches the furnace temperature of 400°C. The formation of γ alumina and corundum is completed by heating 4 hours at 500°C, 43 hours at 450°C, and 91 hours at 400°C. The change to mullite was not investigated in detail because other investigators have published reports on this subject.[8]

Table I shows that the corundum molecule expands between 400° and 750°C and then contracts slightly on further heating to 900°C. When heated to 950°C a sudden contraction takes place to give a value which remains more or less constant within the limits of error in measurements by X-ray methods up to 1700°C. Figure 2 shows some of the X-ray patterns indicating the shift in the corundum lines which are more noticeable when measured accurately.

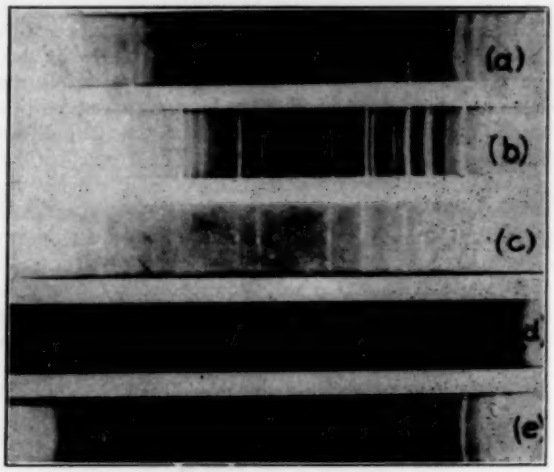

FIG. 2.—(*a*) Diaspore; (*b*) corundum; (*c*) 400°C diaspore; (*d*) 550°C diaspore; (*e*) 800°C diaspore.

Diaspore samples, heated at 110°, 750°, and 950°C, were examined by an optical spectrograph to determine relative amounts of impurities present to give some explanation for the increase in size of the corundum molecule. Each sample was entirely vaporized in a carbon arc to give an analysis which is entirely representative of the material.

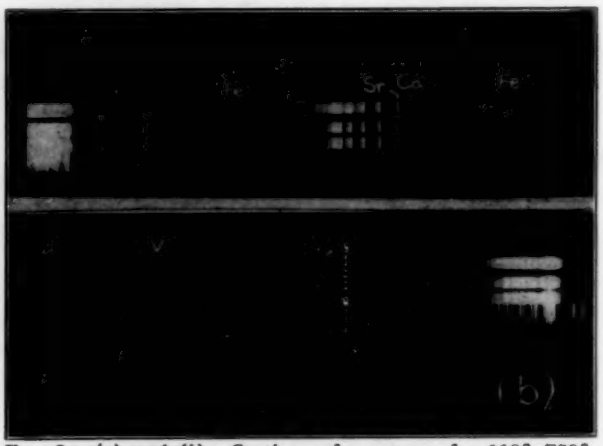

FIG. 3.—(*a*) and (*b*): Sections of spectrum for 110°, 750°, 950° diaspore and iron, respectively.

Figure 3 shows a portion of the spectrogram between the ranges 4000 Å to 2200 Å in the ultraviolet portion of the spectrum. These spectrograms show that traces of iron, nickel, potassium, sodium, titanium, chromium, manganese, vanadium, strontium, and a few other elements are present. An examination of Fig. 3

[8](*a*) T. N. McVay and C. L. Thompson, "X-Ray Investigation of Effect of Heat on China Clays," *Jour. Amer. Ceram. Soc.*, **11** [11] 829–41 (1928).

(*b*) H. Insley and R. H. Ewell, "Thermal Behavior of the Kaolin Minerals," *Jour. Research Nat. Bur. Stand.*, **14** [5] 615–27 (1935); R.P. 792; *Ceram. Abs.*, **14** [8] 201 (1935).

(*c*) J. F. Hyslop, "The Constittuional Changes Occurring in Clays on Heating," *Trans. Ceram. Soc.* [England], **24**, 402–406 (1924–1925).

(*d*) J. F. Hyslop and H. P. Rooksby, "Effect of Heat on Crystalline Break-Up of Kaolin," *ibid.*, **27** [2] 93–96; "Break-Up of Kaolin," [4] 299–302 (1927–1928); *Ceram. Abs.*, **7** [10] 719 (1928); **8** [7] 530 (1929).

shows that all the lines on the pattern of the sample heated to 750°C are slightly more intense than the corresponding lines for the 110°C sample. This increase in intensity means an increase in the percentage of the element present and is brought about by the removal of water from the sample during the heating at 750°C, thus leaving a sample containing a larger proportion of all the residual materials. The 950° pattern shows that only iron, chromium, vanadium, and strontium have been partially eliminated by sublimation during this higher temperature.

V. Conclusions

These data show that commercial diaspore clay on heating does not change materially up to 350°C. Between 350° and 400°C, there is a sudden destruction of the diaspore to form corundum and γ alumina. The formation of γ alumina is relatively rapid up to a temperature of 550°C, when the formation of corundum becomes more rapid, indicating that the γ alumina is being changed to corundum. At 950°C, the γ-alumina has been entirely converted to corundum and there is no further increase in corundum content. From 1050°C to 1200°C, mullite is forming from a combination of the free quartz and combined silica present in the diaspore clay with the corundum.

As the corundum is being formed at 400°C, it apparently is picking up traces of iron, chromium, vanadium, and strontium, which increase the molecular size of the corundum molecule. More of these materials are picked up in solid solution until at 750°C a maximum increase is reached, which on further heating is gradually decreased. At 900°C, there is a sudden elimination of the elements mentioned by sublimation to give a reduction in the size of the corundum molecule. These elements in solid solution are not entirely eliminated even at 1700°C.

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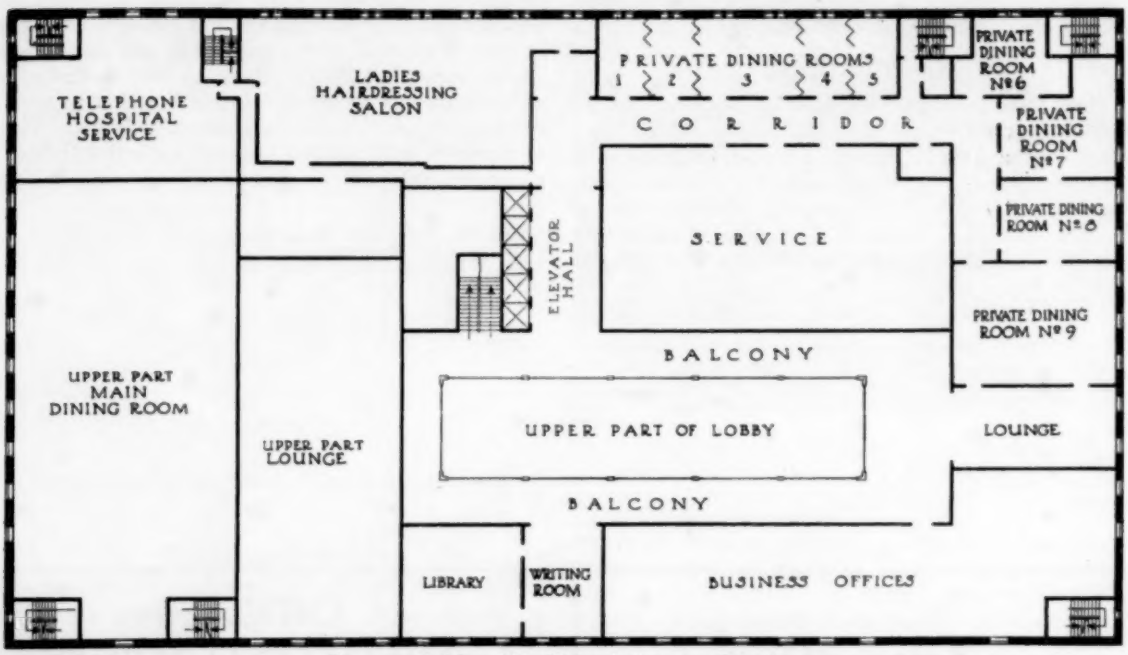
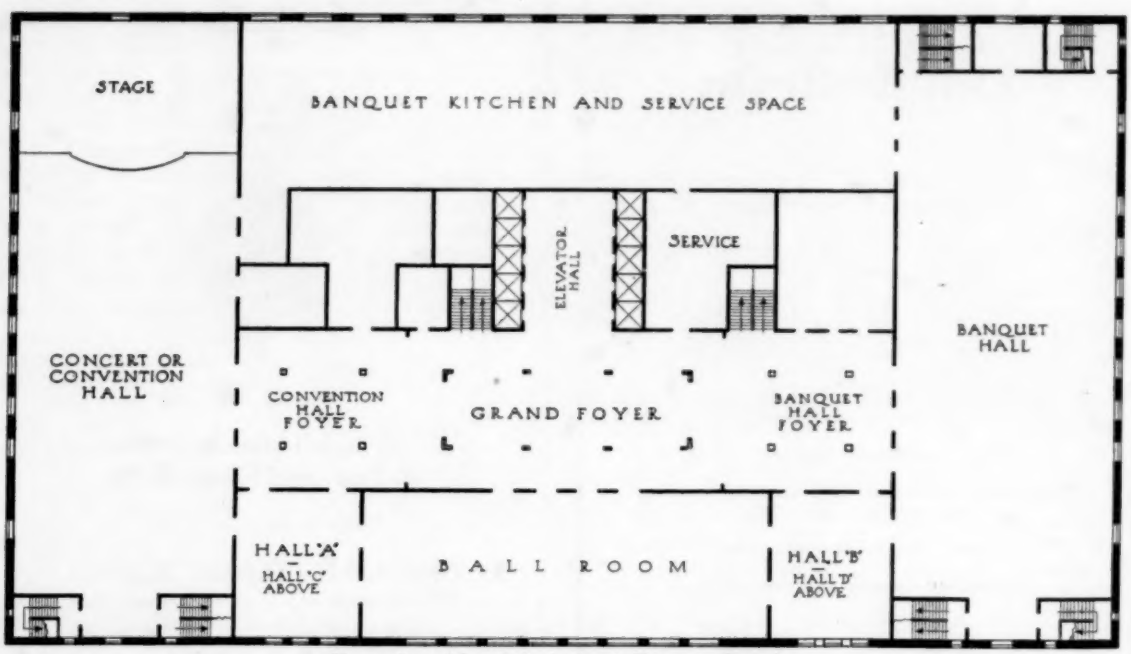


Floor plan of Royal York Hotel, Toronto, Canada



Floor plan of Royal York Hotel, Toronto, Canada

CERAMIC ABSTRACTS

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Journal Reference: The journal name appears in italics, followed by the volume (bold-faced), issue number (in brackets), page numbers, and year (in parentheses).

November, 1939
18—11

Abrasives

Fine grinding of hard-metal tools with boron carbide. W. Dawihl and E. Wesenberg. *Werkstattstechnik*, **33** [15] 373–76 (1939).—Though the grains of B_4C are harder than those of silicon carbide, no practical bond has been found for their use in grinding wheels. Grinding is done with cast iron wheels on the surface of which B_4C mixed with oil as a paste is applied. Pregrinding is always done with SiC. If used for fine grinding, the speed of the B_4C wheel has to be considerably lower than that of the corresponding SiC wheel. The best grain size of B_4C particles is 60 to 100 μ. The time for fine grinding is unchanged. The resulting surface is better than that obtained with SiC within the same time and almost equal to that obtained with diamond powder. Costs are about the same as with SiC. J.M.N.

Grinding and turning of soft rubber. Anon. *Gummi-Ztg.*, **52** [47] 1228 (1938).—A good grade of emery cloth in different particle sizes is employed for the grinding of soft rubber. The emery wheel is used for working square, rectangular, or unround workpieces; wooden wheels can be constructed in various forms and profiles, with emery paper glued onto the wheel or with emery material applied to the wheel. This method has found very satisfactory use. Some aids are given for the turning of soft rubber. D.A.B.

Maintenance in ball manufacturing. W. F. Shedinger. *Mill & Factory*, **25** [2] 79–82 (1939).—Maintenance in ball manufacturing at the Atlas Ball Co., Philadelphia, Pa., is described and illustrated. Some of the technical details considered are forming, heat treating, and grinding of balls from $^7/_{64}$ in. to $2^1/_2$ in. in diameter which must be accurate to ± 0.000025 in. D.A.B.

Polishing stainless steel welds. Anon. *Sheet Metal Ind.*, **12** [133] 583–84 (1938).—The efficiency of grinding wheels can be expressed only in terms of the ratio of the metal removed to wheel wear; the highest possible ratio is obtained only when wheels are running at their maximum cutting speeds which must be kept constant irrespective of load. The characteristics and constructional design of the Hicycle grinder used on all kinds of stainless steel work are described. It is a departure from the orthodox design, as it works on a frequency of 200 cycles instead of 50 cycles and offers the advantage of an absolutely constant cutting speed maintained under all conditions of load. Illustrated. A.P.S.

Precision roll-grinding machines. Anon. *Sheet Metal Ind.*, **12** [133] 530 (1938).—Naxos-Union roll-grinding machines, a guiding feature of which is the elimination of all causes which might lead to vibrations, are described. Although made for over 40 years, new features are continually being incorporated, the latest being the adoption of adjustable steel guideways. The camber grinding attachment, the result of extensive research, is designed on the latest principles and is independent of the position and diameter of the grinding wheel or diameter of the roll; it produces convex and concave curves which clearly correspond with the theoretical curve. A.P.S.

Roll-grinding machines. R. Whibley. *Sheet Metal Ind.*, **12** [130] 177–80 (1938).—W. surveys the theory and practice of modern roll-grinding machines designed to give accurate camber on both hot and cold rolls or to provide truly parallel surfaces. A.P.S.

BOOK

Grinding and Polishing in the Metalware Industry (Schleifen und Polieren in der Metallwarenindustrie). Hugo Krause. Verlagsbuchhandlung Max Jänecke, Leipzig, 1939. viii + 196 pp., 63 illustrations. Price 3.80 Rm. Reviewed in *Chem.-Ztg.*, **63** [29] 260 (1939).—K. discusses the processes of grinding and polishing, grinding stones, massive grinding wheels, disks, brushes for grinding and polishing with loose materials, cleaning and polishing in drums, grinding and polishing pastes and other materials, special methods, grinding and polishing machines, circumference speeds and revolution counters of grinding disks, aids in grinding and polishing, grinding and polishing of numerous metals and ware, and first-aid treatment and accident prevention in the shop. This book is considered good and reliable council. D.A.B.

PATENTS

Abrading tool. L. O. Beard. U. S. 2,170,585, Aug. 22, 1939 (Aug. 8, 1938).

Abrasive articles, e.g., grinding wheels. Deutsche Norton-Ges.m.b.H. Ger. 675,149, April 13, 1939 (May 20, 1935); IV*e*/39*b*. 22.—Abrasive articles such as grinding wheels consist of abrasive particles, an organic binding agent, and a finely divided inorganic filler not exceeding 40% by volume of the binding agent. The filler consists of a highly pulverized insoluble fluoride such as cryolite. D.A.B.

Abrasive-coated articles. Behr-Manning Corp. Brit. 510,328, Aug. 10, 1939 (Feb. 6, 1937).

Abrasive tool. L. J. Kaufman and C. H. Shemchak. U. S. 2,171,254, Aug. 29, 1939 (June 15, 1935).—A valve seat grinding tool.

Apparatus for:

Abrading coatings from rods. J. E. Anderson (General Electric Co.). U. S. 2,170,672, Aug. 22, 1939 (Nov. 27, 1936).

Balancing abrasive wheels during fabrication. O. S. Buckner and D. B. Wilson (Bay State Abrasive Products Co.). U. S. 2,172,006, Sept. 5, 1939 (July 29, 1936; April 26, 1937).

Grinding. S. G. Richardson (Norton Co.). U. S. 2,171,892, Sept. 5, 1939 (Oct. 14, 1936; March 29, 1938).

Lapping or abrading. W. E. Hoke. U. S. 2,170,329, Aug. 22, 1939 (Nov. 10, 1937).

Turning cylindrical round surfaces of abrasive disks which are fixed on working axles. Ewald Brinkmann (Josef Heinrich Bodden). Ger. 676,826, May 17, 1939 (March 25, 1937); XII/67*a*. 26; addition to Ger. 643,911.—Apparatus for turning the cylindrical round surfaces of abrasive disks by means of rotating cutters carries special blade holders which are arranged on a mobile sliding carriage and are led from the rim to the middle of the abrasive disk. Two mobile blade holders are arranged simultaneously parallel to each other on the sliding carriage according to Ger. 643,911. The housing of the sliding carriage is adjusted to work vertically in a mobile manner and rotates horizontally around its middle axis above the abrasive disk to be worked. D.A.B.

Art of lapping or grinding. W. E. Hoke. U. S. 2,170,328, Aug. 22, 1939 (Nov. 10, 1937).

Auxiliary device for interchanging grinding tools, especially segmental grinding heads. Franz Warsow (Deutsche Niles Werke A.-G.). Ger. 674,387, March 23, 1939 (Feb. 27, 1937); XII/67*a*.13.—In an auxiliary device for interchanging grinding tools, especially segmental grinding heads, on a surface-grinding machine with a vertical grinding axle, the grinding tool is attached by means of a firm screwable support ring on a flange joining the grinding axle. A support for the tool feeder is attached to the workpiece bench which has center surfaces in common with the support of the grinding machine and also has center surfaces for attachment of the tool; this is possible only to the extent of half the circumference, to permit attachment of the tool in the case of a low operating grinding axle. D.A.B.

Balancing machine. H. O. Fuchs (General Motors Corp.). U. S. 2,171,927, Sept. 5, 1939 (Jan. 26, 1938).

Cambering mechanism for grinding machines. Charles Herfurth and K. T. Schledorn (Cincinnati Grinders, Inc.). U. S. 2,167,948, Aug. 1, 1939 (April 25, 1938).

Coated abrasive articles. Behr-Manning Corp. Brit. 510,329 to 510,332, Aug. 10, 1939 (Feb. 6, 1937).

Crankshaft grinding tool. E. M. McGovern and Paul Schrick (Lempco Products, Inc.). U. S. 2,171,417, Aug. 29, 1939 (July 26, 1938).

Cylindrical grinding machine for shoulder grinding. L. A. Williams and A. C. Racine (Norton Co.). U. S. 2,170,613, Aug. 22, 1939 (Dec. 22, 1937).

Device for grinding the bearing surface of locomotive wheels. Walter Pilz. Ger. 674,145, March 16, 1939 (July 20, 1937); XII/67*a*. 10.—The effective working surfaces of a grinding device are so arranged that both bearing wheels of a set are worked simultaneously with the same grinding tool whose axis is perpendicular to the axis of the wheels. D.A.B.

Diamond tools. Coventry Gauge & Tool Co., Ltd., S. J. Harley, and J. E. Wainwright. Brit. 509,809, Aug. 2, 1939 (April 5, 1938).

Finishing tool for grinding wheels. Dilumit-Werk G.m.b.H. Ger. 661,051, May 12, 1938 (March 4, 1936); XII/67*a*. 26.—A finishing tool for grinding wheels is provided with a mobile socket fixed on ball bearings or rollers around a pinion which carries several ring-shaped turning elements. The individual turning elements are loosely arranged on the supports so that they can be turned with various angular velocities on the carrier. D.A.B.

Gear wheel grinding apparatus. M. G. E. Philippe (Société dite: La Bougie B. G.). U. S. 2,172,032, Sept. 5, 1939 (April 30, 1937).

Grinding machine. C. G. Flygare (Norton Co.). U. S. 2,170,606, Aug. 22, 1939 (Feb. 10, 1939). Hans Ernst and A. H. Dall (Cincinnati Grinders, Inc.). U. S. 2,170,494, Aug. 22, 1939 (Oct. 20, 1936).

Grinding machine. E. A. Koether (Koppers Co.). U. S. 2,169,252, Aug. 15, 1939 (July 23, 1936).—In a grinding machine, the combination of a flat face grinding member, a second member facing it, one of the members at least comprising two independent concentrically arranged grinding elements rotatable independently of one another about a common axis, and means for rotating the members and the concentrically arranged elements independently of each other.

Grinding machines, lathes, and like machine tools. H. J. C. Forrester (Ultra-Prazisionswerk Ges.). Brit. 510,979, Aug. 23, 1939 (April 11, 1938).

Grinding and polishing disk. Otto Gratwohl. Ger. 674,568, March 30, 1939 (Sept. 3, 1934); XII/67*c*. 1.—A grinding and polishing disk is composed of sections of a strong multiweft fabric. D.A.B.

Grinding to and fro within work with an eccentric adjustable disk. Oskar Ludwig (Röchling'sche Eisen- und Stahlwerke G.m.b.H.). Ger. 676,465, May 11, 1939 (Dec. 3, 1936); XII/67*a*. 9.—The grinding disk is arranged on a pinion bent at right angles and lying eccentric to the axis of the carrying collar of the tool so that the bending of the pinion is equal to the eccentricity of the arrangement of the bent pinion opposite the axis of the carrying collar. The axis of the driving arbor for the grinding disk carries a toothed pinion wheel at its free end and falls in or coincides with the axis of the eccentric arrangement of the bent pinion; the grinding wheel is separated from it by means of an inner cog system joining with the pinion and notching with the toothed pinion wheel D.A.B.

Grinding wheel truing apparatus. C. C. Alvord (Norton Co.). U. S. 2,171,516, Sept. 5, 1939 (Dec. 10, 1938). C. G. Flygare (Norton Co.). U. S. 2,170,605, Aug. 22, 1939 (Feb. 19, 1938). W. H. Wood (Norton Co.). U. S. 2,171,902, Sept. 5, 1939 (May 4, 1938).

Hand-operated sharpening or polishing device. R. Wineberg. Brit. 510,553, Aug. 16, 1939 (Feb. 19, 1938).

Honing device. H. T. Wendt. U. S. 2,172,720, Sept. 12, 1939 (March 8, 1939).—A machine for polishing a brake drum.

Honing machine. A. M. Johnson (Barnes Drill Co.). U. S. 2,171,271, Aug. 29, 1939 (Oct. 15, 1938). J. E. G. Kline (Carborundum Co.). U. S. 2,171,799, Sept. 5, 1939 (Dec. 10, 1936).

Hydraulically operated surface-grinding machine. A. G. Belden and C. G. Flygare (Norton Co.). U. S. 2,171,519, Sept. 5, 1939 (Aug. 20, 1938).

Machine for grinding articles to predetermined forms. Charles Day. U. S. 2,171,211, Aug. 29, 1939 (April 22, 1938).

Machines for grinding or sharpening knives, etc. R. D. Ewart. Brit. 509,498, Aug. 2, 1939 (Dec. 15, 1937).

Making abrasive articles. N. P. Robie and W. D. Rossow (Carborundum Co.). U. S. 2,171,635, Sept. 5, 1939 (Aug. 21, 1936).—A process of manufacturing abrasive articles comprises wetting granular abrasive material

with substantially pure water, mixing dry powdered condensation resin with the wetted granular material, drying the coated granules to cause the granular material to become coated with resin, and applying sufficient heat to a mass of the coated granules to unite the granules into a unitary structure.

Manufacture of abrasive wheels. R. J. GOODNOW AND D. B. WILSON (Bay State Abrasive Products Co.). U. S. 2,172,243, Sept. 5, 1939 (June 16, 1938).—In the manufacture of abrasive wheels, a step involves placing a resilient liner in a mold of a length greater than the length of the article being molded and axially compacting the abrasive material and liner simultaneously to provide a radial compacting of the material.

Method and apparatus for burnishing. WILLIAM LOCKHART (National Steel Barrel Co.). U. S. 2,170,533, Aug. 22, 1939 (Oct. 8, 1935; renewed Feb. 11, 1939).

Polishing mechanism. ENFIELD CYCLE CO., LTD., AND H. T. GUISE. Brit. 510,558, Aug. 16, 1939 (Feb. 26, 1938).

Relieving mechanisms, particularly for spiral-bevel cutter grinding machines. D. BROWN & SONS (Huddersfield), LTD., J. GOULDER, AND H. E. MERRITT. Brit. 510,472, Aug. 16, 1939 (March 19, 1938).

Roll-grinding machines. J. E. POLLAK (Dayton Rubber Mfg. Co.). Brit. 511,350, Aug. 30, 1939 (Dec. 14, 1937).

Tool for fine working of threads on the inside of hollow objects. HERBERT FÜSSENHAUSER (Maschinenfabrik Augsburg-Nürnberg A.-G.). Ger. 674,567, March 30, 1939 (Nov. 29, 1937); XII/67*a*. 31.03.—A tool for the fine working of threads located within hollow objects is provided with radially moving grinding stones fixed in grooves on the rim of the wheel. The radial motion of the rim is brought about by sliding bars independent of each other which are connected by a belt system with a common pulley whose belt runs in a zigzag manner over rollers on the sliding bars and the rollers on the pulley. D.A.B.

Truing attachment. CHARLES HERFURTH (Cincinnati Grinders, Inc.). U. S. 2,170,304, Aug. 22, 1939 (Dec. 6, 1937).

Workpiece support for producing round bolts on a centerless abrasive machine. WILLI HANDEL (Schnellpressenfabrik Koenig & Bauer A.-G.). Ger. 675,651, April 27, 1939 (June 28, 1937); XII/67*a*. 24.01.

D.A.B.

Art and Archeology

Frederick Carder, artist and glass technologist. ALEXANDER SILVERMAN. *Bull. Amer. Ceram. Soc.*, **18** [9] 343–49 (1939).

Gateway to Arabia: Ezion-Geber. NELSON GLUECK. *Asia*, **39**, 528–32 (1939).—A very large jar bearing a South Arabic inscription was found this year. Such lettering also occurred in Hureidha. The construction of the mud brick houses at the two sites is almost identical. Ezion-Geber was a great factory site which was built on virgin soil and not on ruins. The factories were made of sun-dried brick, excellently made and skillfully laid. King Solomon built this town to smelt his iron and copper ores which were shipped in exchange for luxuries. The outer fortification wall and gateway were found. The wall was 25 ft. high and 12 ft. thick at the base. The original town was destroyed and rebuilt four times due to conflict between Judah and Edom. Much evidence of the construction of boats was found. In the fifth city, black glazed Attic ware of the 5th century B.C. was found. There were also fragments of pottery with Aramaic inscriptions. See "Temple—," *Ceram. Abs.*, **18** [10] 263 (1939).

W.D.F.

Liverpool delftware, pottery, and porcelain exhibit. ANON. *Jour. Roy. Soc. Arts*, **87** [4524] 987 (1939).—To stimulate local civic pride, delftware, pottery, and porcelain from the Liverpool museum and H. B. Lancaster's collection were displayed in store windows. The exhibits attracted much attention.

K.R.

Meeting competition of decal ware with hand-painted pottery. ANON. *Ceram. Ind.*, **29** [2] 110–15 (1937).—The Southern Potteries, Inc., at Erwin, Tenn., has as its main line of production a low-priced hand-painted underglaze ware. It is the only general ware or earthenware plant producing such products in quantity and at a price to compete with the decal ware commonly produced. Though the plant is quite modern in its operation, the hand-decorated underglaze ware is developed with native mountain labor and all hand painting is done by local girls trained at the plant. The output is approximately 2500 dozens per day. Modern equipment in the plant is described.

E.J.V.

Photography on porcelain. M. MAKOVER. *Sovet. Foto*, **1937**, No. 8, pp. 28–29; *Chem. Abs.*, **33**, 5757 (1939).—For the production of pigment images on glazed porcelain by photographic means, a process is described which is essentially the same as that proposed by Poitevin (*Procédé*, **13**, 91–93 (1911)). A mixture of sugar and dextrin with $K_2Cr_2O_7$ coated on a glass plate is exposed under a negative for about the same time required by printing-out paper. A positive image is then developed by dusting on a powdered cement pigment. The image is then covered with a thin layer of collodion, washed in H_2O, stripped from the glass, and applied to the porcelain surface. The porcelain is then heated to a temperature of about 600°, at which the glaze fuses and combines with the pigments in the image.

Prizes in pottery design. ANON. *Jour. Roy. Soc. Arts*, **87** [4523] 945–46 (1939).—The Royal Society of Arts in London offers as a prize in pottery design a traveling fellowship of 100£. Eight entries were received for the 1939 competition. In the preliminary contest, not more than four designs, recently executed, could be submitted by a candidate. These were to include (*a*) tableware such as fish sets, dinner sets, or dessert sets or (*b*) modelled figures, animal or human, suited for reproduction in earthenware or china. A choice application of color was suggested as desirable. The jury chose three of the eight candidates to participate in the final stage of the competition. Twelve hours were then allowed in which the selected designers could attempt one of the following subjects: (1) a design for a tea service, which should be a free modern translation of 18th century style, the decoration to include a suitable version of the Society's Flaxman medal; or (2) a design and model of a group consisting of an animal and a tree, suited to a mantelpiece of the same period. The design of the tea service gained honorable mention for Miss Audrey Samuel. It was to be decorated with brown underglaze print and red enamel color. The first prize award went to Miss Winifred Smith for her plasticine model of a group composed of a lamb (a quite delightful British one), a protesting bird, and a low conciliatory tree. Illustrated.

K.R.

Royal gift. H. DEMEULDRE. *Verre & Silicates Ind.*, **10** [20] 234–35 (1939).—Among the gifts to the Queen of Holland from the King of Belgium were 12 plates from the Porcelain Factory of Brussels, Demeuldre-Coche Firm. The plates were made on the oldest series of molds in the factory which has guarded the multiple secrets of manufacture throughout the years. Plates of the same shell pattern have been in the Palace of Brussels over 100 years. The paste was made according to the old formula. Scenes from 19th century Belgian cities are painted by hand in the center of the plates, and the rims have a shell-like relief with salmon ground; the edges of the shells are touched with mat gold.

M.V.C.

Ruins of Nishapur. JOSEPH M. UPTON. *Asia*, **39**, 445–49 (1939).—Nishapur is in northeast Iran and on the old trade routes from Europe to China and to Afghanistan. Most of the excavation has been in the mound Sabz Pushan. Here a building was found decorated with intricately carved and colored plaster panels made about A.D. 970. Fragments of polychrome plaster squinches with both Sasanian and Hellenistic elements are of an

earlier date; some wall paintings on plaster show the same influence. Pottery, probably made here, dating from the 8th to 10th century was white with decorations of black Arabic letters; a bowl with polychrome figures of humans, animals, and birds for decoration was also found. A slightly earlier type with a bold, clear design had no red on it. Still another type, dating from the 8th to 11th century, is a local imitation of the polychrome splashed ware made in China under the T'ang dynasty. A square plaster lantern was found, with round openings on the side originally covered with glass. See "Iranian—," *Ceram. Abs.*, **18** [9] 230 (1939). W.D.F.

BOOKS

American Potters and Pottery. JOHN RAMSAY. Hale, Cushman, & Flint, Boston, 1939. 304 pp., 91 illustrations. Price $3.75.—R. has achieved a compilation of historical data and a classification of early American pottery that is unique and valuable even though he has made erroneous technical statements. In the beginning of Chapter I and throughout his treatise, he emphasizes "pottery" as a distinct class, one of four. "Previous writers have detailed the qualities and characteristics of hard- and soft-paste porcelains . . . completely foreign to our simple American ware, and then added insult to injury by slighting that completely. Jervis, in his really excellent Cyclopaedia of Ceramics, . . . devotes one short paragraph out of 670 post quarto pages to the slipware pottery of Pennsylvania and dismisses Mercer's experiments in that technique with the words, 'the whole effort seems one of wasted energy.'" R. limits the definition of "pottery" as "table, household, and storage vessels and utensils or ornaments made from colored bodies." Inasmuch as this treatise is devoted largely to colored body pottery of America, he does injustice to present-day "American Potters and Pottery" by the scant space devoted to them. This seems to be more an error in the use of too broad a title for the book. R. gracefully covers this lack on page 115: "An outline of the development of white earthenware and porcelain in the United States, written from the collector's viewpoint, must neglect the earliest period, since it is, to the collector, almost legendary, so rare are examples of its ware. Consequently, more attention has been paid to the childhood and adolescence of this American industry, with its manifold trials and tribulations. Now, because of the deadline set at the year 1900, since the collector is not interested in ware of more recent origin, the industry must be left at the very beginning of its full growth. This has continued steadily, with improvement in every direction and a constantly growing support from the American public, until the present day. Now the world can send us nothing better than our own productions in the field of fine tableware. And the largest whiteware factory in the world, with a number of others, produces cheaper grades of ware which still compare very favorably with those of other countries. So that, even if the triumphant last act must be reduced to a synopsis, the many gloomy earlier passages thus fall into place as incidents in a slow but certain progress."

The title of the book, "American Potters and Pottery," is deceiving to one not informed of the limitation in definition which R. has adopted for pottery, viz., colored clayware. He is true to his definition of American pottery in that his definitions, his description of potteries, and his check list of potters are devoted chiefly to the earlier potteries making redware, stoneware, brownware, and yellow ware. Only twenty-five pages are devoted to earthenware and porcelain.

In his introduction, R. says that his check lists of potters and of pottery marks are "possibly the most important sections of the book and its strongest claim to a place on the collector's shelf." The arrangement of the list of potters is partly geographical, partly alphabetical, and partly chronological. To see how confusing this is, for instance, look for the potteries of Berks County, Pennsylvania. Geographically they are in the list covering Eastern Pennsylvania, New Jersey, Delaware, Maryland, and Eastern West Virginia; alphabetically by town names; and chronologically only in the town grouping. This presentation may be the clearest possible arrangement but certainly not until after a thorough study is made of it.

Essentially a book for collectors, it has a value. Its presentation is novel in form and interesting in text. The bibliography of 108 books is valuable and apparently exhaustive. The index is admirably complete.

R.C.PURDY

Civilization of Assyria and Babylon (La Civilisation d'Assur et de Babylone). G. CONTENAU. Payot, Paris, 1937. Price 30 fr. Reviewed in *Antiquity*, **13** [50] 159–70 (1939). A.B.S.

Excavations at Telloh Under the Direction of H. de Genouillac: Vol. II, Eras of Ur, Third Dynasty, and of Larsa (Fouilles de Telloh sous la direction de H. de Genouillac: Epoques d'Ur iiie Dynastie et de Larsa). ANON. Paul Geuthner, Paris, 1937. Price 400 fr. for Vols. I and II. Reviewed in *Antiquity*, **13** [50] 159–70 (1939). A.B.S.

Music of the Sumerians. F. W. GALPIN. Cambridge University Press, 1937. Price 18s. Reviewed in *Antiquity*, **13** [50] 159–70 (1939). A.B.S.

Pottery of the American Indians. HELEN E. STILES. E. P. Dutton & Co., Inc., New York, 1939. 169 pp. including bibliography and index. 125 illustrations. Price $2.50.—S. teaches the history of a people through an examination of their pottery and shows how all handcrafts grow out of the daily needs of the people, how all the materials used are those most easily obtainable, and how the designs symbolically interpret the feelings, ideas, and religion of the people. A detailed description is given of how pottery is made, the tools employed, and the objects, animals, and ideas that inspire the designs. The renaissance of the arts and crafts of the Indians in Mexico whose leaders are teaching them to be proud of their precious heritage of handcrafts is also described. The outstanding persons and families now engaged in the pottery business lend considerable human interest to the book. Chief among them are Maria Martinez of San Ildefonso and Julian, her husband, of World's Fair fame. Line drawings and decorations were done by Marion Downer.

PATENTS

Color-grading system. W. M. COHN. U. S. 2,169,355, Aug. 15, 1939 (Aug. 17, 1936).—The method of color grading objects normally presenting a color indicating a desired classification and a somewhat different color indicating undesirability as to the classification comprises illuminating such objects with light having line-spectrum characteristics of the color indicating the desired classification, simultaneously illuminating the objects with light of substantially continuous spectrum characteristics whereby contrast between the color indicating desired classification and other colors will be accentuated, at the same time maintaining approximately the normal appearance of such objects, and separating objects of the desired color from those of other colors.

Designs for:

Bottle. F. E. A. W. BERGAUD. U. S. 116,214, Aug. 22, 1939 (June 20, 1939). J. L. DUNNOCK (Swindell Bros., Inc.). U. S. 116,556, Sept. 12, 1939 (June 24, 1939). J. S. STEELMAN (Armstrong Cork Co.). U. S. 116,173, Aug. 15, 1939 (Dec. 30, 1938).

Dish. G. N. ALLEN AND PASCAL L'ANGLAIS (Oneida, Ltd.). U. S. 116,211, Aug. 22, 1939 (June 11, 1938).

Glass covered butter dish. F. S. BARBIERS (Anchor-Hocking Glass Corp.). U. S. 116,157, Aug. 15, 1939 (May 29, 1939).

Cements

Composition of cement as key to durability in sea water. ANON. *Concrete, Cement Mill Ed.*, **47**, 196–97 (1939).—A high silica, low alumina Portland cement (low in tricalcium aluminate) will best resist sea water. The high alumina cements do not have tricalcium aluminate; they have a monocalcium aluminate which is much more stable and will not react with the sulfate. These cements successfully resist sea water. Another type is Portland-pozzuolana cements. Pozzuolana is a substance which will react with lime in the presence of water and form cementitious compounds. The purpose of pozzuolana is to react with lime liberated by the hydration of the cement. There is a wide variety of pozzuolanas of many different compositions; it is therefore hard to establish standards for them. W.D.F.

Major trends in mechanical phases of cement manufacture. C. S. LINCOLN. *Concrete, Cement Mill Ed.*, **47**, 143–44 (1939).—The length of kilns has steadily increased until now some are 400 ft. long. For grinding, a three compartment pebble mill is used. W.D.F.

Transformations of hydraulic cements. MARCEL LEPINGLE. *Compt. Rend. 18me Congr. Chim. Ind.*, **1938**, 283–95; *Chem. Abs.*, **33**, 6017 (1939).—The expansion curves of different types of cement (more particularly aluminous cements for refractory mortars and concrete) were determined up to 1000°. The curves reveal the existence of a certain number of singular points and anomalies which not only are useful from a practical standpoint but seem capable of furnishing information on the transformations that take place in the elemental constituents of hydraulic cements.

PATENT

Simultaneous production of white Portland cement and iron. KARL JANISCH, FRANZ KAESS, AND CARL ZIEKE (Bayerische Stickstoff-Werke A.-G.). Ger. 675,721, April 27, 1939 (Dec. 28, 1936); VI/80*b*. 3.18.—White Portland cement and iron are produced simultaneously by fusion in an electric furnace. Iron-free dolomite stone is used as a primary material with the addition of bauxite and lime. D.A.B.

Enamel

Applications of cerium, zirconium, and titanium compounds in the manufacture of enamels for metals and ceramics. MAX PAQUET. *Compt. Rend. 18me Congr. Chim. Ind.*, **1938**, 1096–1107; *Chem. Abs.*, **33**, 6550 (1939).

Double output in cast-iron enameling with two-coat, one-fire ware. ANON. *Ceram. Ind.*, **29** [2] 108–109 (1937).—The George D. Roper Corp., Rockford, Ill., abolished the use of ground coat for its cast-iron parts and is using leadless enamel frits applied directly over the iron. This method saves one firing, and due to the improved method of stacking the ware in the furnace the output of the department has been more than doubled. Illustrated. E.J.V.

Effect of alumina gel on the properties of enamel slip: III. K. P. AZAROV AND N. M. SERDYUKOVA. *Kolloid. Zhur.*, **4**, 699–704 (1938); *Chem. Abs.*, **33**, 6550 (1939).—Slips were prepared by mixing feldspar, clay, $Al(OH)_3$ gel, K_2CO_3, and water in various ratios. The density, humidity, alkalinity, elasticity, and plasticity of the products were determined. $Al(OH)_3$ increases the stability of feldspar suspensions and makes them thixotropic. See "Properties—." *Ceram. Abs.*, **18** [1] 12 (1939).

Gas-fired hood furnaces for sheet steel annealing. ANON. *Sheet Metal Ind.*, **13** [143] 365–66 (1939).—An installation for annealing steel sheets is described. It is a rectangular furnace equipped with vertical hot tubes, burners, a lifting device, a number of brick-lined bases on which the sheets are stacked, and an equal number of corrugated inner covers which are kept over the charge during the cooling period after removal of the furnace cover. A.P.S.

Gas opacification of vitreous enamels. ANON. *Foundry Trade Jour.*, **59** [1150] 165 (1938).—The results obtained by Ignaz Kreidl show that it is possible to obtain a higher degree of opacity by gas opacification alone than by the use of even the most intense "solid" opacifier when this is also used alone. Gas opacification is achieved by the addition of a gas-producing medium to the enamel in the grind. The medium volatilizes during the firing of the enamel, and the bubbles formed by the volatile gases impart the requisite degree of opacity. Control of the manufacture insures that the bubbles are all of a very minute size and, owing to the nature of the enamel, it is impossible for these bubbles to escape and give an enamel of inferior opacity even on overfiring. The enamels are claimed to be more resistant to overfiring than the enamels of the "solid" opacifier type. The principle can be applied to both the wet- and dry-process enamels. H.E.S.

Handling plant for enamel constituents. GOTHIC WORKS OF R. & A. MAIN, LTD. *Foundry Trade Jour.*, **59** [1150] 166 (1938).—A modern installation of handling equipment for enamel constituents designed to reduce dust hazards and at the same time reduce handling costs is described. H.E.S.

How the foundry can provide good enameling castings. M. E. MANSON. *Ceram. Ind.*, **29** [1] 39–40 (1937).—Blistering or boiling in enamels is generally due to the iron. Cast iron can be tested by chemical analysis; the ideal iron from an enameling standpoint would show no combined carbon present. Testing the pig iron by enameling small specimens is advocated. The use of good pig iron, a high percentage of remelt, and no plumbago or graphite facings in the foundry are recommended. A number of suggested causes of blistering is listed. E.J.V.

Opacification of white enamels. R. ALDINGER. *Keram. Rundschau*, **46** [31] 343–44 (1938).—The preopacification of the frit and the opacification of the mill addition are dealt with. Faulty expressions, such as apparent opacity and true opacity, must be avoided. F.E.V.

Oxidation of iron and adhesion of enamel. J. WHITE. *Foundry Trade Jour.*, **59** [1142] 14–16 (1938).—Recent investigations show that the enameling of iron involves reactions between the oxides of iron and the enamel. The reactions occurring after the fusion of the enamel are believed to be as follows: (1) the initially formed scale (which normally at fusion has reached a thickness of 7 to 10 microns) dissolves in the enamel glass giving it a green coloration; at this stage the iron oxide content of the enamel is mainly in the ferrous condition; (2) the total iron oxide content of the enamel increases, while, at the same time, the proportion of ferric oxide to ferrous oxide increases; (3) the enamel becomes saturated with Fe_3O_4 which begins to separate as minute black crystals. At the same time a second scale begins to form on the surface of the metal, and good adhesion of the enamel is obtained even in the absence of adhering oxides. During the third stage, ferric oxide crystals appear, and the enamel is overoxidized. The function of adhering oxides such as cobalt oxide is to (1) increase the solvent power of the enamel for the initial oxide scale, and (2) facilitate the formation of the second oxide layer, presumably by speeding up the rate of oxygen diffusion through the glass by acting as oxygen carriers due to their various oxide forms. Nickel and manganese, the oxides of which are also used to promote adherence, each have several oxide forms. The high-temperature chemistry of the oxides of iron is also discussed. H.E.S.

Planning and equipment of a modern pickling plant. ANON. *Sheet Metal Ind.*, **13** [144] 491–92 (1939).—The new pickling plant installed at the West Bromwich Works of J. B. and S. Lees, Ltd., for pickling lengths and coils of strip is described. Illustrated. A.P.S.

Preparation and milling of sheet-iron and cast-iron enamels. B. B. KENT. *Foundry Trade Jour.*, **59** [1155]

255–56 (1938).—The importance of mill-room operation and control is stressed. Adequate room for milling operations, screening, sinks, storage bins, sampling, etc., is required. Individual drives are advocated for grinding mills. Modern practice is to load mills to three quarters of their capacity: 45% grinding agents and 30% frit are recommended. Good running speeds are, for a 1000-lb. mill, 25; a 300-lb. mill, 30; a 100-lb. mill, 35; a 50-lb. mill, 40; a 20-lb. mill, 50; and a 10-lb. mill, 60 r.p.m. The use of a standard unit of fineness is desirable. Color matching is facilitated by the saving of control plaques for each batch of new color prepared, with directions for milling. The pickling-control apparatus, such as pickling pills for testing acid and alkali tanks, is considered part of the mill-room equipment. The cleaning of spray-gun equipment, especially after the completion of each shift, is urged. H.E.S.

Reactions noted during the smelting of an enamel. HAROLD A. SCHWARTZ. *Ceram. Ind.*, **29** [2] 119–20 (1937).—Using a typical ground-coat enamel with dehydrated borax, S. studied the batch heating curve to determine the type of gases evolved during smelting, the time of evolution, the amount of each gas evolved, and the weight loss during smelting. The water being driven off is believed to cause the lag in the heating curve. The irregularity in the heating curve at 1150° to 1450°F may be due partly to the feldspar (melting over a temperature range of 1170° to 1300°F) and borax (melting at 1360°F) and partly to the evolution of fluoride gases. Soda niter probably promotes the evolution of oxygen. The maximum amount of CO_2 was noted at 810°F. E.J.V.

Remove carbon from iron and steel by heat treatment. A. E. BADGER AND B. W. KING, JR. *Ceram. Ind.*, **29** [1] 41 (1937).—Small amounts of carbon present in iron and steel are objectionable if the metal is to be exposed to atmospheric corrosion or is to be used in the vitreous enameling industry. In the enameling industry, the presence of excessive carbon (free or combined) may lead to blistering and perhaps to reboiling. To produce irons which may be enameled without blistering, it is necessary to remove only part of the carbon from a surface layer of the metal. This may be easily done by heating the metal in an atmosphere of hydrogen gas. The efficacy of this treatment was shown by a test with a sample of high-carbon steel which was then enameled. E.J.V.

Sandblasting as applied to the vitreous enameling process. H. WHITAKER. *Foundry Trade Jour.*, **59** [1142] 12–13 (1938). **Discussion.** WHITAKER ET AL. *Ibid.*, [1146] 90–91; see *Ceram. Abs.*, **17** [10] 325 (1938). H.E.S.

Scientific aids to control in vitreous enameling. J. G. PEARCE AND G. T. O. MARTIN. *Foundry Trade Jour.*, **59** [1159] 333–38 (1938).—The rapidly increasing popularity of vitreous enamel finishes has created a demand for methods of testing and control which can be systematically applied to raw materials, to the process at appropriate points during production, and to the finished product. Scientific control enables standards to be settled by the management. Tests and apparatus employed are discussed. Of the various tests described, those for opacity and adherence are the most important. Opacity, or reflectance, can now be very accurately measured, but adherence, whether estimated by means of thermal expansion or by mechanical tests, cannot be satisfactorily estimated. **Discussion.** TAIT ET AL. *Ibid.*, [1163] 412–14, 416. H.E.S.

Sheet-iron enamel defects traceable to the base metal or metal-forming operation. E. E. HOWE. *Jour. Amer. Ceram. Soc.*, **22** [10] 348–54 (1939).

Testing the hardness of enamels. HEIMSOETH AND WEINIG. *Emailwaren-Ind.*, **16** [25–26] 160–66 (1939).—A study was made to determine whether hardness is an additive property of simple enamels as are other mechanical and thermal properties, i.e., whether it is possible, with the help of factors for the separate constituents, to determine in advance the approximate hardness from the percentage composition of enamels as is done in computing the expansion. For this purpose, an exact physically defined hardness figure must be determined, and no empirical value, such as the scratch width or the abrasion of the surface by grinding with an abrasive, will serve. The testing method perfected by the Vickers Co. is superior to all other methods because physically exact values are defined in the dimensions kg./mm.^{2}. The method is rapid, reliable, and easy and is an adaptation of the Brinell hardness testing method for metals; instead of the ball, a four-sided diamond pyramid with an "opening angle" of 136° operates under a certain load on the test piece, and the surface of the impression is determined. Vickers hardness does not depend on the load and is therefore practicable for very hard and brittle substances. The Vickers hardness figure is easily calculated from the formula

$$V = \frac{\text{load}}{\text{surface}} = \frac{P \times 2 \sin 68°}{\Delta^2} = \frac{P \times 1.8554}{\Delta^2} \text{ kg./mm.}^2,$$

where P = the load and Δ = the length of the diagonal (in mm.). The impression can be easily ascertained and measured with the Dia-Testor, a hardness tester. The picture of the impression appears on the mat sheet of the apparatus directly after the test and can be measured and qualified according to the degree of hardness. Even for enamels the impression is sharply defined. In the case of brittle enamels, fine cracks go into the enamel from the edges of the pyramid. A series of tests was made to determine the effect of oxides on the hardness of enamel. Additions of the oxides (5%) were fused with the constant parent batch, and the enameled test pieces were fired. As there is no difference in the hardness of enamels fired once or twice, firing, when properly conducted, has little effect on the hardness. The Vickers hardness figure of the parent enamel represented the physical constant. Values for the oxides are tabulated. Errors amounted to about 4%. Lithium and B_2O_3 did not change the hardness of the original enamel; Na_2O and K_2O lowered it markedly. Al_2O_3, SiO_2, beryllium, fluorides, and ZnO increased the hardness; antimony oxide increased it enormously. Another series of tests was made to determine if the hardness of finished enamels can be computed from the factors of the separate constituents. Hardness is not a strictly additive property in the sense that the influence of components on the hardness of enamels does not remain constant with increasing additions, but there is the possibility that, within the usual ordinary concentrations, the separate enamel formers affect hardness linearly, and factors may be found from which hardness can be approximated. The effect of some mill additions on the hardness was studied, and the results are given in a table; 3% additions of tin oxide and cerium oxide did not affect the hardness; zirconium oxide and quartz powder increased it. Sodium metantimonate greatly increased the hardness. M.V.C.

Use of metallic abrasives. J. E. HURST AND W. TODD. *Foundry Trade Jour.*, **59** [1163] 408–12 (1938); see *Ceram. Abs.*, **18** [5] 118 (1939). H.E.S.

SEPARATE PUBLICATION

Lecture course on enameling iron: XIV, Questions and answers about the making, selection, and use of iron and steel sheets for porcelain enamel finishes. INLAND STEEL CO. AND A. I. ANDREWS. Inland Steel Co., Chicago, 1938–39. 4 pp.—Superopaque enamels are one of the major developments which indicate the progressive trend of the enameling industry, along with improvements in automatic operations in the plants. The more common tests for acid and alkali resistance, scratch hardness, reflectivity, and gloss are discussed. For Parts VII–XIII see *Ceram. Abs.*, **18** [7] 175 (1939). F.J.Z.

PATENTS

Acid-resistant enamel. SOC. DES PRODUITS CHIMIQUES DES TERRES RARES. Fr. 842,881, Sept. 1, 1938; *Chem.-Ztg.*, **63** [47] 417 (1939). D.A.B.

Apparatus for manufacturing porcelain enamel and glass. G. H. MCINTYRE AND G. R. SYLVESTER (Ferro Enamel Corp.). U. S. 2,169,611, Aug. 15, 1939 (May 20, 1935).—An apparatus for the refining of a continuous stream of

melted porcelain enamel material, glass, etc., comprises the combination of means for discharging a continuous stream of melted material, an annular fining chamber divided into a plurality of independent sections, means for moving the fining chamber relatively to the stream of melted material to successively fill different compartments of the fining chamber, an annular water bath associated with the fining chamber, and a perforate basket in the water bath for the reception of fined material discharged from the compartments.

Supporting structure for porcelain-enameled pans. A. C. MAUS (Roesch Porcelain Construction, Inc.). U. S. 2,171,221, Aug. 29, 1939 (March 30, 1939).

Glass

Annealing one-gallon wine bottles in direct-fired city gas lehr. W. B. DODDS. *Ceram. Ind.*, **33** [3] 46–47 (1939).—Regular metered city gas of 525 B.t.u. per cu. ft. is used for firing glass-annealing lehrs at the Metro Glass Bottle Co., Jersey City, N. J. Over 20,000 heavy 1-gal. bottles are annealed each day in one of the four gas-fired continuous annealing lehrs. Production is on a 24-hr. per day schedule. The lehr is 98 ft. long, and a 1-gal. bottle takes slightly over 2 hr. to traverse it as the temperature is gradually lowered from 1000°F to room temperature. The construction of the lehr is rather standard. Gas is delivered at high pressure, compressed after metering in a reciprocating pump which supplies the four lehrs and six feeders. Gas is fed to eight high-pressure inspirators in each lehr, where proper amounts of air for combustion in oxidizing flames are entrained. Manifolded to these inspirators are ten burner manifolds extending halfway across the lehr. By firing with gas, it is possible to have a larger number of smaller individually adjustable heat-producing elements, conducive to a more even heat distribution across the lehr and a subtler adjustment of temperature gradients along the length of the lehr. Operation is clean and lehr gases are free from constituents which might have deleterious effects upon the ware. No trace of "bloom" appears on the product and no special gas-purifying equipment is used. Besides superior controllability and convenience, the negligible effect of the cost of fuel upon over-all cost of the bottles is a decided advantage. Illustrated. L.M.C.

Behavior of glass in regard to torsion requirements. H. SCHARF. *Glastech. Ber.*, **17** [6] 173–80 (1939). J.F.H.

Coloration of glass with selenium. G. C. PRIDDEY. *Glass*, **16** [8] 326 (1939).—A brief review is given. B.C.R.

Deformation of glass rods under tension. Application to the study of the viscosity of glass at low temperatures. J. A. CAHOUR. *Compt. Rend. 18me Congr. Chim. Ind.*, **1938**, 1050–56; *Chem. Abs.*, **33**, 6009 (1939).—The methods generally used for measuring the viscosity of liquids are not applicable in the case of glass at low temperatures. A method for measuring very high viscosities has been developed, based on the rate of elongation of a rod of the substance subjected to tension parallel to its axis. By this method it was shown that, below the transformation point, glasses (even those which seem perfectly annealed, i.e., exhibiting no double refraction) undergo a slow evolution which tends to bring them to a vitreous state which is much more stable than that normally observed. Study of these well-stabilized glasses shows that their properties do not undergo any modification at the transformation point.

Development and present status of the gob feeder. A. WENDLER. *Glastech. Ber.*, **17** [6] 180–85 (1939). J.F.H.

Effect of GeO_2 admixtures on the optical properties of glass. K. A. KRAKAU. *Optiko-Mekh. Prom.*, **9** [4] 15–17 (1939).—Literature and experimental data show that the introduction of germanium into glass by means of partial or total replacement of silica by GeO_2 increases the index of refraction and dispersion of glasses. Laboratory meltings in platinum crucibles of six glasses in which silica was partially replaced by GeO_2 and in whose composition other changes were made (increase in B_2O_3) showed that (1) the replacement of SiO_2 by GeO_2 lowers the chemical stability of glasses, and (2) viscosity of glasses is considerably diminished by the introduction of GeO_2, less time is required for melting the glass, and purification is facilitated. M.V.C.

Effect of Sb_2O_3 on the purification and on a series of physicochemical properties of glass. K. G. KUMANIN. *Optiko-Mekh. Prom.*, **9** [1] 5–11 (1939).—Experiments showed that Sb_2O_3 introduced into a glass batch in the presence of saltpeter and As_2O_3 is an excellent purifier for glasses which cannot be purified by saltpeter and arsenic alone. This addition of Sb_2O_3 also has a favorable effect on the crystallization capacity of glasses and their absorption of light and increases their chemical resistance. M.V.C.

Effect of some factors on the process of silvering glass. V. M. VINOKUROV AND B. N. MOSKVIN. *Optiko-Mekh. Prom.*, **9** [5] 21–23 (1939).—Reducers obtained by the inversion of sugar with nitrogen have various reducing effects. A series of experiments was carried out to determine the effect of methods of production of the reducer on the process of glass silvering. Inversion was made with sulfuric, nitric, and acetic acids. Reducing proceeded so rapidly (when silvering with sugar inverted with 0.2 *N* nitric acid) that 5 min. after mixing the silver solution no longer contained silver ions. The effect of ions formed on dissociation of silvering solutions is being studied. M.V.C.

Firoll lehr provides maximum fuel economy and efficient annealing for pressed and blown glass ovenware. TOLEDO ENGINEERING CO. *Nat. Glass Budget*, **54** [27] 3, 17 (1938). Illustrated. H.E.S.

Furnace-draft regulation of glassmelting furnaces. E. R. ENGSTROM. *Nat. Glass Budget*, **54** [9] 16 (1938).—Accurate furnace pressure control stabilizes the entire operation of the glass tank. The simplicity of the Askania Jet Pipe Principle is shown. The apparatus consists of a jet pipe which swings on a hollow vertical pivot through which the operating medium (usually oil) is supplied to the jet pipe at an adjustable pressure (about 80 lb. per sq. in.) and at high velocity. As the oil stream leaves the jet pipe it strikes at two closely adjacent holes in the distributor which communicate to the two sides of a double acting piston. The slightest change in impulse pressure moves the jet pipe, causing the oil to strike either the right or left hole of the distributor. As a result, the piston is moved to correct for the impulse variation. As soon as equilibrium is established, the jet pipe returns to its center position. H.E.S.

Glass wool best for winter protection of plants. CORNING GLASS WORKS. *Nat. Glass Budget*, **54** [29] 9 (1938). H.E.S.

Improved melting practice at Ford's glass plant. ANON. *Ceram. Ind.*, **33** [3] 53–55 (1939).—In order to reduce the amount of batch segregation at the River Rouge, Mich., plant of the Ford Motor Co., the raw batch is briquetted. The briquettes, which are pillow-shaped and about 2 in. square, contain no cullet because it shortens the life of the briquetting rolls. The glass tank, rebuilt in 1938, is probably the only one in the country that does not have a dog house. Briquettes and cullet are introduced into the tank through nichrome alloy tubes cooled by water jackets. The melting end of the regenerative tank is heated by six ports; a mixture of coke-oven and blast-furnace gas is fired through luminous flame burners. A silica brick and sillimanite curtain wall is inserted between the refining and melting ends to give more absolute control over the relative temperatures. The curtain wall is raised or low-

ered by two jack screws; the wall, however, has not been raised or lowered for several months, but remains in such a position that the gap between the melt and the curtain wall is about 18 in. Construction of the curtain wall is described in detail. Glass from the refining end of the tank passes through a set of cast-iron rolls water-cooled from within and through the gas-fired annealing lehr which has a patented burner system that provides a uniform rate of annealing with a minimum of fuel. Burners are arranged in automatically controlled units, and each zone is controlled by a potentiometer type of controller. In the grinding operation, sand is reclaimed after each operation, saving thousands of dollars a year. Complete descriptions of all unusual equipment are included. Illustrated.

L.M.C.

Influence of Neophane glass on the visibility of interference patterns in white light. C. SCHAEFER AND J. ROSEMANN. *Z. Tech. Physik*, **20** [7] 193–98 (1939).—The authors demonstrate theoretically and experimentally that the use of Neophane glass considerably improves the visibility of interference patterns in white light.

W.M.C.

Multicellular glass and its possibilities. FEODOR GOLDIS. *Verre & Silicates Ind.*, **10** [17] 199–201; [19] 221–23 (1939).—Multicellular glass with a special woodlike structure, called *lignoverre*, is destined to replace commercial woods because of its cheapness (cellular artificial resins are still expensive) and the abundance of its raw materials; it is fireproof, lightweight, highly resistant to chemicals, imputrescible, smooth, thermally insulating, and can be sawed, nailed, filed, drilled, and glued. The glass has the same resistance as wood, can be welded with a blowpipe, is opaque, and can be dyed any color. The basic factor in multicellular glass is the elementary pellicle forming the walls of the hollow cells which in turn form a sponge. Technical problems for improving the sponge, based on the study of the qualities of wood, attempts to imitate the configuration, size, and form of the cells of wood, and attempts to attain the resistance of wood fiber by adaptation of the pellicle are discussed for the interest of manufacturers. The special sponge, with elongated cells oriented along a single axis and walls about 0.001 mm. thick, is obtained mechanically by the injection of gas or vaporizing products. The apparatus of G. consists of an autoclave into which the liquid glass is pumped and compressed air heated to 1400° is forced, causing a rapid ebullition and the elongation of the cells. The foam formed passes out through a nozzle and cools rapidly. Specially treated *lignoverre* is also used for paper, electric cables, artificial leather, and safety glass. Entire new industries will be developed through its use.

M.V.C.

Opal glass. ANON. *Elec. Rev.*, **124** [3212] 871–72 (1939).—Examination of opal glass for illuminating uses in thin sections under the microscope showed that it consists, in most instances, of a matrix of clear glass holding in suspension particles varying from 1 micron down to 0.2 micron in diameter. X-ray diffraction studies showed that the particles are generally composed of sodium and calcium fluorides. Glasses of different opacities were obtained from the same batch by different cooling rates. In many cases, glasses were transparent when molten, developing opacity on cooling. "Bad" glasses, those with high light absorption and low diffusion, had very small particles. "Good" glasses, those with low absorption and high diffusion, had relatively large particles. Reports on the general theory of opal glasses were presented to the British Standards Institution subcommittee dealing with diffusing materials in August, 1929, and January, 1931, by J. W. Ryde, B. S. Cooper, and W. A. R. Stoyle (*Ceram. Abs.*, **12** [7] 256 (1933)). A photomicrograph and photograph are given.

J.L.G.

Physics in the glass industry. ALFHEUS SMITH. *Ohio State Univ. Eng. Expt. Sta. News*, **10** [3] 12–13 (1938).—When Abbe developed many types of optical glass, he had to measure index of refraction, dispersion, transparency, and double refraction. Another field of study includes glasses which transmit only certain regions of the spectrum, such as railroad signal glasses and glasses transmitting ultraviolet light. In the automatic production of glassware, precise temperature control is necessary to keep the viscosity constant. A glass may be heat-treated to increase shock resistance. Investigation of the dielectric strength led to the use of glass in insulators for power and telephone lines and in radio tubes. The density and thermal expansion have also been studied. An example of low thermal expansion glasses is the Pyrex group. The new finely drawn glass fibers are used for heat insulation, and heat conductivity must be measured. These glass fibers are also used as electrical insulation. For the production of the 200-in. telescope disk, a low thermal expansion glass was needed which had to be well annealed. Methods for melting and pouring had to be worked out.

W.D.F.

Pipe lines of glass. F. SIEPER. *Kolloid-Z.*, **86,** 60–62 (1939).—Examples are shown for connecting glass pipes with flanges, bushings, etc.; their use in the chemical industry is described. Illustrated.

L.E.T.

Production efficiency in a small glass plant. H. V. KAEPPEL. *Ceram. Ind.*, **29** [2] 116–18 (1937).—K. describes the efficiently operated modern plant of Glass Containers, Inc., Los Angeles, which is producing bottles of all kinds in amber and flint glass. Illustrated.

E.J.V.

Pump of glass. ANON. *Mill & Factory*, **25** [2] 140, 144 (1939).—A pump for pumping corrosive liquids and chemical products is constructed of clear, chemical-resistant glass and is to be used in conjunction with glass piping. The pump is of the centrifugal type, has a balanced glass rotor, and is capable of safely and economically handling 6000 gal. of liquid 70 ft. above suction level.

D.A.B.

Refractive index and dispersion of optical glasses in the photographable infrared. H. BRAUCKHOFF. *Z. Instrumentenk.*, **59** [4] 154–62; [5] 181–90 (1939).—The method used and the results of an investigation of 10 optical glasses of Schott & Co. are fully described; the refractive indices were determined for the range up to 11,400 Å (photographically). Some simple formulas were derived from which the refractive indices in the investigated infrared range can be calculated with an exactness of four decimals by means of the Abbe number, $(n_D-1)/(n_F-n_C)$, and of the mean dispersion, (n_F-n_C). The color errors of lenses can be corrected as well in this range as in the visible range. Complete tables are given for each glass.

M.H.

Relation between fine structure and the physical properties of glasses. Criticism. W. BILTZ. *Glastech. Ber.*, **17** [6] 186 (1939). **Reply to criticism.** E. KORDES. *Ibid.*, p. 187; see *Ceram. Abs.*, **18** [8] 207 (1939).

J.F.H.

Significance of impurities in coal in the glass industry. UNITED GLASS BOTTLE MANUFACTURERS, LTD. *Combustion Appliance Makers' Assn. [Solid Fuel] Preprint*, April, 1939, 4 pp.; *Brit. Chem. & Phys. Abs.-B*, **58** [7] 719 (1939).—The injurious effects of Fe and S on glass quality are discussed. Serious trouble is avoided if the coal employed contains less than 1% of total S.

Solubility of minerals of quartz sand in glass melts. M. A. BEZBORODOV, A. S. ZAPOROJTZEVA, AND G. G. MOÏSEEVA. *Bull. Glavstroisteklo*, **1939,** No. 5, pp. 7–18; *Jour. Soc. Glass Tech.*, **23** [97] 138A (1939).—The authors describe their experimental work on studying the rate of solubility of the different minerals of sand at various temperatures and at various states of continuity in glass melts. The glass dissolves zircon and kyanite much more slowly than it dissolves quartz, and it dissolves feldspar, rutile, biotite, magnetite, ilmenite, and other minerals more rapidly than quartz. The composition of the glass has an influence on the rate of solution of quartz. Magnesium oxide renders the solution of quartz in the glass melt more difficult.

Spectrophotometric properties of the principal colored glasses used in passive resistance against nocturnal air attacks. BERNARD LONG. *Compt. Rend. 18me Congr. Chim. Ind.*, **1938,** 296–99; *Chem. Abs.*, **33,** 6009 (1939).—The absorption characteristics of blue glasses which are

generally used for obtaining mild outside lighting are given. The filtering of automobile headlights through orange CdS or Se glasses reduces their visibility by aerial observers. By combining windows made of Nd oxide and Cu oxide glass with interior artificial yellow lighting, plants operating at full capacity at night are invisible from the air.

Stirring optical glass during melting. K. S. EVSTROP'EV AND M. M. SKORNYAKOV. *Optiko-Mekh. Prom.*, **9** [2] 14–15 (1939).—The importance of stirring optical glass during melting to obtain greater homogeneity is discussed with special regard to (1) effect of the solubility of pot walls and the soiling of the glass by small bubbles with rapid stirring, (2) maximum speed of stirring in large pots, (3) shape of the stirring equipment and its material, and (4) casting of optical glass. M.V.C.

Testing medicinal glasses by means of narcotin and methyl red. L. SPRINGER. Translated in *Glass*, **16** [6] 238–39 (1939); see *Ceram. Abs.*, **18** [10] 267 (1939). B.C.R.

Thermolux glass in modern industry. ANON. *Verre & Silicates Ind.*, **10** [18] 205–209; [20] 230–33; [21] 241–46 (1939).—Further advantages of using Thermolux glass for factory windows and roofs are presented. Thermolux is more efficient than other glass for admitting light into interiors where the depth is greater than the height of the glass surface. It transmits a light without coloration which permits better recognition of colors. The coefficient of heat loss is about half that of other glasses. Because of the low coefficient of heat conductivity of Thermolux, the greater part of the heat waves is reflected by the glass silk incorporated in Thermolux. Thermolux protects against the formation of condensation and insulates against noise; it is twice as resistant as ordinary glass and has the same technical characteristics as wire glass. The economy obtained in the construction of a factory where Thermolux is used in a peaked roof with symmetrical slopes is shown by a study of a project for glass roofing a modern factory. See *Ceram. Abs.*, **18** [8] 208 (1939). M.V.C.

Translucent walls. ANON. *Sprechsaal*, **72** [14] 176 (1939).—Hollow glass building blocks are made from glass blown or pressed into different forms and models which present no technical difficulties in building. The blocks are grooved, and mortar joints are 5 mm. wide. Translucent brick are not transparent, but afford a well-dispersed light without dazzle or many shadows. They insulate against heat, cold, and sound and are durable. M.V.C.

BOOKS AND SEPARATE PUBLICATION

Directory of German Glass Industry, 1939–1940. ANON. "Die Glashütte," Dresden, June, 1939. 29th ed. 568 pp. Appendix 116 pp. Price 6 Rm.—The directory consists of the following parts: (I) Glassworks, including (*a*) index of German glassworks with names of firms in alphabetical order, (*b*) location of factories, (*c*) index according to regions and provinces, and (*d*) inactive or discontinued factories; (II) Location of plants for working and refining glass; (III) German wholesale glass business; (IV) Commercial representatives of the German glass industry; (V) State testing institutions and laboratories, including professional glass associates, German technical schools for the glass industry, organizations in the glass industry, management groups with branches and divisions, societies, unions, associations, etc.; and (VI) Sources of supply lists for glass and glassware and technical literature for the glass industry. M.V.C.

Surface Tensions of Molten Glass: I. C. W. PARMELEE AND K. C. LYON. *Univ. Illinois Eng. Expt. Sta. Bull.*, No. 311, pp. 5–27 (1939).—The importance of surface tension of molten glass for operations in the manufacture of glass is commented on, and methods of measuring it are discussed. The most satisfactory results are obtained with the maximum bubble-pressure (Jaeger) method by the formula, $T = pr/2\ (1-2r/3h)$, where T = surface tension in dynes per cm., p = (total pressure − hydrostatic pressure) on bubble in dynes, r = radius of the tip of the tube (for producing the bubble) in cm., and h = the height of a column of test liquid equivalent to p in cm. The results from 7 glasses with compositions of 10 to 30% Na_2O, 10 to 25% B_2O_3, and 55 to 75% SiO_2 indicate that addition of silica to a soda-boric oxide-silica glass causes a rise in the surface tension of the glass and that the general tendency of the addition of soda or boric oxide to such glass is to reduce the surface tension. **II, Surface Tensions of Soda-Lime-Silica Melts.** C. W. PARMELEE AND C. G. HARMAN. *Ibid.*, pp. 29–47.—The surface tensions of soda-silica and soda-lime-silica melts are rapidly increased by addition of calcium oxide; at 1350°C, this increase amounts to 3.0 to 1.8 dynes per cm. for each 1% of CaO added. The surface tensions of soda-silica melts have a minimum at about 72% silica at 1350°C. The surface tension increases about 1 dyne per cm. for each 1% increase in silica from 72% or each 1% Na_2O. An increase in silica from 72 to 80% raises the surface tension from 278.0 to 280.5 dynes per cm. Addition of CaO to soda-silica melts decreases the effect of Na_2O and SiO_2 on surface tension; the minimum point moves to lower SiO_2:Na_2O ratios with increasing CaO. Melts with 15% CaO show an increase in surface tension from 3.5 dynes per cm. at 68% silica to 3.8 dynes per cm. at 51% silica. The surface tension is nearly proportional to the CaO content, while curves of constant viscosity tend to parallel lines of constant SiO_2. The temperature coefficient of surface tension decreases with addition of CaO; a minimum is reached at a SiO_2:Na_2O ratio of about 3.5. Tests are given in full. See "Maximum—," *Ceram. Abs.*, **17** [8] 275 (1938). M.H.

World Directory of the Glass Industry, 1938. ANON. Müller & Schmidt, Coburg, 1938. 1016 pp. Price 14.50 Rm; foreign 15.50 Rm.—The directory contains an index including the following parts: (I) Glassworks in Europe, Asia, Africa, North and South America, Australia; (II) European water glass and smelting works; (III) Quartz glass industry; (IV) Workshops for glass blowing; (V) Workshops for grinding, engraving, refining, painting, printing, etching, bending glass, silvering mirrors, sandblasting, mosaic works; (VI) List of representatives of the glass industry; (VII) German accident insurance association for the glass industry; this part also includes professional training schools for the glass industry, German technochemical laboratories, offices of heat economy, organization of the glass industry, glass trade in Germany, and glass industry associations, societies, and companies; and (VIII) Trade marks, together with a list of products, the location and distribution of firms, etc. M.V.C.

PATENTS

Altering the inner wall of hollow glass objects. ANTON KÖNIGSHEIM (Vereinigte Lausitzer Glaswerke A.-G.). Ger. 676,665, May 17, 1939 (July 17, 1937); VI/32*a*. 8.—The inner wall of hollow glass objects is altered or decorated by introducing material into the object by an attachment on a blowpipe. The material is applied in a fragmental, pulverized, gaseous, or liquid state. D.A.B.

Apparatus for:

Bending glass sheets. PILKINGTON BROS., LTD., L. J.-B. FORBES, AND G. W. T. BIRD. Brit. 510,254, Aug. 10, 1939 (Jan. 29, 1938).

Bending and tempering glass sheets. A. H. STEVENS (Pittsburgh Plate Glass Co.). Brit. 509,775, Aug. 2, 1939 (Jan. 20, 1938).

Feeding molten glass. T. F. PEARSON (Crown Cork & Seal Co., Inc.). U. S. 2,171,096, Aug. 29, 1939 (Sept. 7, 1937).

Finishing glassware. W. L. WAGNER, SR. U. S. 2,169,455, Aug. 15, 1939 (July 2, 1937).

Grinding and polishing a continuous glass band. F. B. WALDRON AND F. E. SLOCOMBE (Pilkington Bros., Ltd.). Ger. 675,650, April 27, 1939 (March 9, 1938); XII/67*a*. 15.—An apparatus for attaining a medium for working a glass band in machines for grinding and polishing a continuous glass band by means of several pairs of tools which grip on both sides of the glass simultaneously has grinding and polishing tools consisting of revolving disks working against the band in a definite fixed intermediate position. The pair of abrasive tools functioning together on opposite sides of the glass band are

supported by frames which are put into place by an adjusting apparatus which is transverse to the feeding direction of the moving glass band. The degree of regulation is about equal for each tool and corresponds to the deviation at the middle of the glass band at which position the tools work against the band and continuously adjust themselves to the varying middle positions. D.A.B.

Manipulating glass plates. WILLIAM OWEN (Pittsburgh Plate Glass Co.). U. S. 2,169,739, Aug. 15, 1939 (Sept. 8, 1937).

Manufacturing a continuous glass band. PILKINGTON BROS., LTD. Fr. 847,828, Dec. 20, 1938. D.A.B.

Packing glass sheets. C. D. BURRELL (Libbey-Owens-Ford Glass Co.). U. S. 2,169,677, Aug. 15, 1939 (Sept. 25, 1937).

Producing a continuous glass strip. PILKINGTON BROS., LTD., AND E. B. LE MARE. Brit. 510,799, Aug. 23, 1939 (Feb. 8, 1938).

Producing ground or polished glass strip. PILKINGTON BROS., LTD., G. H. BAILLIE, AND F. B. WALDRON. Brit. 511,543, Aug. 30, 1939 (Feb. 22, 1938).

Transforming tubes. JAKOB DICHTER. Ger. 676,625, May 17, 1939 (Sept. 15, 1934); VI/32*a*. 27.—An apparatus for transforming glass tubes has an attachment for holding one end of the tube fast during the working of the other end. The tube is securely held by a mobile pin arranged in the same axis as the tube holder in the form of a lengthwise-running blowpipe. The pin can be pushed lengthwise in and out of the holder and leads to the glass tube. D.A.B.

Apparatus and procedure for feeding molten glass. F. L. O. WADSWORTH (Ball Bros. Co.). U. S. 2,172,895, Sept. 12, 1939 (March 15, 1935; renewed May 21, 1937).

Automatic fabrication of glass objects having their edges turned in. VERRERIE HEMAIN. Fr. 846,836, June 3, 1938. D.A.B.

Automatic machine for the manufacture of bottles, etc. SOC. ANON. D'ÉTUDES ET DE CONSTRUCTIONS D'APPAREILS MÉCHANIQUES POUR LA VERRERIE. Fr. 847,478, June 17, 1938. D.A.B.

Composite tumbler. W. A. MORTON (Amco, Inc.). U. S. 2,169,426, Aug. 15, 1939 (Oct. 14, 1936).—A composite tumbler comprises a body of glass having a threaded portion, a metallic receptacle having engagement with the threaded portion thereof and having a wall coextensive with a substantial portion of the tumbler out of contact therewith, and resilient material interposed between the lip of the receptacle wall and the outer wall of the tumbler to seal the space between the receptacle and tumbler when they are joined at their threaded portions.

Compound glass. RÖHM & HAAS G.M.B.H. Ger. 674,712, March 30, 1939 (Dec. 29, 1934); IV*c*/39*b*. 27.—The layer rendering the glass shatterproof consists largely or entirely of mixed polymers or polymer admixtures of vinyl acetate and the butyl ester of acrylic acid (the methyl or ethyl ester of acrylic acid may also be used). D.A.B.

Continuous production of glass having a plurality of layers. NEUE GLASINDUSTRIE-GES. Brit. 509,653, Aug. 2, 1939 (July 19, 1937).

Device for producing partially closed hollow objects of quartz, quartz charge, and other materials fusing at high temperatures. ERICK LEONHARDT (I. G. Farbenind. A.-G.). Ger. 676,756, May 17, 1939 (Dec. 30, 1936); VI/32*a*. 35.—Partially closed hollow objects of quartz, etc., are produced by a receptacle used for the simultaneous melting and forming of the object. A regulable closing device is arranged at the base, which contains a closing plate adapted to form an opening for removing the section constituting the inner form; the apparatus has a base plate provided with small openings. D.A.B.

Drop bottle. HUGO KRATZ. Ger. 676,021, May 4, 1939 (May 8, 1935); IX/30*g*. 1.—A drop bottle is provided with several drop grooves on the rim of the neck. The inner edge of the neck rim is beveled or tapered between the drop grooves which extend to the neck in such a manner that the liquid passes between the drop grooves along to the rim of the bottle neck through the tapered edge. D.A.B.

Electrical glass-cutting apparatus. I. G. FOWLER AND J. L. DRAKE (Libbey-Owens-Ford Glass Co.). U. S. 2,169,687, Aug. 15, 1939 (Nov. 4, 1935).

Examination of transparent solid materials. TRIPLEX SAFETY GLASS CO., LTD., A. C. WAINE, AND F. DIN. Brit. 509,851, Aug. 2, 1939 (Jan. 24, 1938).

Fluxing agent for decolorizing glass. SIOTO G.M.B.H. Ger. 674,524, April 21, 1939 (Nov. 11, 1935); VI/32*b*. 2. Addition to 674,450 (*Ceram. Abs.*, **18** [9] 232 (1939)).—A decolorizing agent for glass consists of a siliceous glass fluxing agent which contains an admixture of decolorizing agent in an amount necessary for decolorizing the entire glass mass. D.A.B.

Furnace for heating glass plates for tempering. L. J.-B. FORBES (American Securit Co.). U. S. 2,170,749, Aug. 22, 1939 (Feb. 7, 1936).

Glass-engraving machine. L. E. RICE. U. S. 2,171,007, Aug. 29, 1939 (April 5, 1938).

Glass fabric. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE ST. GOBAIN, CHAUNY & CIREY. Fr. 847,114, June 10, 1938. D.A.B.

Glass-grinding machine for simultaneous application of several designs on glasses, etc. ADOLF FEHSE AND ARTHUR EWALD (Patent-Treuhand-Ges. für elektrische Glühlampen m.b.H.). Ger. 675,927, May 4, 1939 (Dec. 24, 1936); XII/67*a*. 18.—A glass-grinding machine for applying designs on glasses, etc., has abrasive tools so arranged that they are automatically placed on and lifted off the glass during its rotation. The machine consists of two or more chucks for clamping the glass into place during application of the design; these clamping devices turn the glass in the longitudinal axis of the machine and are on supports which are mobile to and fro in the longitudinal direction of the machine. Two or more revolving shafts, which are parallel to the longitudinal axis of the workpiece, run through the clamp supports and act as supports for the abrasive tools; the tools are applied to and removed from the workpiece by these shafts. The revolving abrasive wheels are attached to supports whose collars are connected to the shafts in such a manner as to render them either mobile or immobile in the longitudinal direction of the machine. Attachments are provided for moving the shafts in the longitudinal direction during the turning of the glasses, etc. D.A.B.

Glass press with tilting form supports. EMIL FRANZ PREISSLER (Firma Fr. Wilhelm Kutzscher). Ger. 675,266, April 13, 1939 (Dec. 15, 1937); VI/32*a*. 17.—The form supports are provided with attachments which can be extended at the place where the pressing takes place by means of a rigid but adjustable rachet device which prevents the lifting up of the forms in the event of upward movement of the press die and the form ring. D.A.B.

Glass tile. N. H. CEDERQUIST. U. S. 2,169,720, Aug. 15, 1939 (March 5, 1938).

High-pressure metal-vapor electric discharge lamps. GENERAL ELECTRIC CO., LTD., AND K. G. SCHNETZLER. Brit. 509,801, Aug. 2, 1939 (March 11, 1938).

Improving the properties of glass for filaments. I. G. FARBENIND. A.-G. Fr. 847,037, Dec. 5, 1938. D.A.B.

Machine for the automatic manufacture of glass bottles, etc. E. ROIRANT AND SOC. ANON. D'ÉTUDES ET DE CONSTRUCTIONS D'APPAREILS MÉCANIQUES POUR LA VERRERIE. Brit. 511,323, Aug. 30, 1939 (June 29, 1938).

Machine for manufacturing bottles. H. C. DAUBENSPECK AND T. B. KITSON. Fr. 847,210, Dec. 7, 1938. D.A.B.

Making glass. R. H. BARNARD. U. S. 2,172,899, Sept. 12, 1939 (April 11, 1938).—The method of making glass panels for glazing comprises moving plastic glass in the form of a relatively flat hollow cross sectional shape longitudinally, collapsing the edges of the hollow form, collapsing the hollow form transversely at spaced locations only while the glass is plastic so that the collapsed portions unite into seams to define hollow panels sealed around their edges, and separating the panels substantially at the transverse seams.

Manufacture of fibers from glass, etc. A. E. EDWARDS (N. V. Mij. tot Beheer en Exploitatie van Octrooien). Brit. 511,333, Aug. 30, 1939 (Oct. 8, 1938).

Manufacture of glass fibers. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE ST. GOBAIN, CHAUNY & CIREY. Fr. 847,795, June 25, 1938. D.A.B.

Manufacture of mineral wool fibers. DEUTSCHE EISENWERKE AKT.-GES. Brit. 511,391, Aug. 30, 1939 (July 17, 1937).

Manufacturing materials and workpieces of mineral wool and a hydraulic binding medium. DEUTSCHE EISENWERKE AKT.-GES. Brit. 510,778, Aug. 23, 1939 (Dec. 31, 1937).

Material for protecting the edges of multilayer shatterproof glass. WILHELM EHRLICH (Elektro-Osmose Graf Schwerin Ges.). Ger. 674,838, April 6, 1939 (Nov. 11, 1936); XII/39*a*. 17.51.—The edges of multilayer shatterproof glass are protected by applying an organic thermoplastic artificial resinous band around them. This band is fixed around the edges without overlapping the sides of the glass. D.A.B.

Method and apparatus for joining glass sheets, etc. A. H. KAMPFER. Fr. 847,354, Dec. 10, 1938. D.A.B.

Method and apparatus for making multicellular glass. CORNING GLASS WORKS. Brit. 510,839, Aug. 23, 1939 (Nov. 5, 1937).

Method and apparatus for producing slag wool, rock wool, etc. O. EVANS (Hein & Co. vorm. Haigerer Hutte). Brit. 511,149, Aug. 23, 1939 (Feb. 11, 1938). Brit. 511,348, Aug. 30, 1939 (Feb. 11, 1938); divided out of 511,149.

Method and apparatus for producing thread from glass and materials which are plastic when cold. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE ST. GOBAIN, CHAUNY & CIREY. Fr. 847,392, Dec. 12, 1938. D.A.B.

Method and means for forming unbreakable lenses. E. G. LLOYD. Brit. 510,007, Aug. 10, 1939 (Dec. 28, 1936).

Method and means for measuring and indicating irregularities in the diameters of tubes, cylinders, etc. J. WATTS. Brit. 509,718, Aug. 2, 1939 (Jan. 25, 1938).

Method of producing lenses. T. W. BUTTNER (Robinson-Houchin Optical Co.). U. S. 2,169,404, Aug. 15, 1939 (May 28, 1937).—A method of making a lens comprises placing two individual lenses together which are of such a shape that they form a space therebetween and which contact with each other at their edges only, placing the coöperating lenses in a furnace heating chamber, bringing the temperature of the furnace to a predetermined degree to heat the lenses to a predetermined degree below their melting point, evacuating the heating chamber so as to withdraw fluid from the space between the two lenses while they are maintained at the predetermined temperature, subjecting the edges only of the lenses to a flash of heat to cause the edges to fuse together without causing distortion of the body portion of the lenses, and then gradually lowering the temperature of the heating chamber to anneal the composite lens.

Molded glass articles and methods of making. BRITISH THOMSON-HOUSTON CO., LTD. Brit. 509,742, Aug. 2, 1939 (Dec. 21, 1937).

Optical glass. G. W. MOREY (Eastman Kodak Co.). U. S. 21,175, Aug. 15, 1939 (May 9, 1939); reissue of original 2,150,694 (*Ceram. Abs.*, **18** [5] 127 (1939)).—A transparent optical glass having an index of refraction (n_D) for the D line greater than 1.65 and a dispersive index greater than both 385—200 n_D and 99—40 n_D, resulting from fusion of a glass batch containing less than 10% silica and containing at least 20% by weight of oxides selected from the group consisting of the following elements: titanium, yttrium, zirconium, columbium, lanthanum, hafnium, tantalum, tungsten, and thorium.

Perfection of apparatus for bending plastic sheets, e.g., glass sheets. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE ST. GOBAIN, CHAUNY & CIREY. Fr. 847,669, Dec. 16, 1938. D.A.B.

Prismatic glassware. GENERAL ELECTRIC CO., LTD., AND J. CHRISTOPHER. Brit. 509,799, Aug. 2, 1939 (March 10, 1938).

Producing articles in molded glass. COMPAGNIE FRANÇAISE POUR L'EXPLOITATION DES PROCÉDÉS THOMSON-HOUSTON. Fr. 847,869, Dec. 21, 1938. D.A.B.

Producing glass building blocks. J. E. BAUER (Owens-Illinois Glass Co.). U. S. 2,170,602, Aug. 22, 1939 (June 29, 1937).

Producing glass objects consisting of several parts. WILLARD P. ZIMMERMANN AND MINOT K. HOLMES (A.-G. der Gerresheimer Glashüttenwerke vorm. Ferd. Heye). Ger. 676,666, May 17, 1939 (Oct. 20, 1937); VI/32*a*. 24.04.—Glass objects constructed of several parts, e.g., hollow glass building blocks, are produced by joining the individual parts by heat and pressure. The edges of the material to be joined are dipped into a bath of molten material to render the glass plastic before joining; material which does not adhere to glass and whose boiling point lies above the softening point of the glass, e.g., lead, is used. D.A.B.

Producing a preliminary thread or yarn consisting of glass fibers. CLAUS SIEGFRIED (A.-G. der Gerresheimer Glashüttenwerke vorm. Ferd. Heye). Ger. 675,267, April 13, 1939 (Nov. 17, 1936); VI/32*a*. 25.—The glass fibers are brought into direct contact with the producer drum which revolves around its axis at a regulable speed and the thread or yarn is removed in its entirety from another place on this drum as crude thread or yarn; a force acts on the thread which favors adherence to the drum lining. D.A.B.

Producing safety glass. RÖHM & HAAS G.M.B.H. Ger. 676,672, May 17, 1939 (April 4, 1932); IV*c*/39*b*. 27.—The base applied between the glass sheets for rendering the glass shatterproof consists of polymers of derivatives of monobasic unsaturated carboxylic acids of three carbon atoms provided with ethylene groups. Polymerizing acrylic or methyl acrylic acid esters of propyl, butyl, or amyl alcohols may be used alone, in a mixture with each other, in the form of mixed polymers, or mixed with other polymers which are used for the production of safety glass, with or without known admixtures as softeners. D.A.B.

Production of glass fibers. N. V. MIJ. TOT BEHEER EN EXPLOITATIE VAN OCTROOIEN. Brit. 509,580, Aug. 2, 1939 (Dec. 30, 1937).

Recovery of wastes from glass grinding and polishing operations. N. S. GARBISCH. Brit. 510,241, Aug. 10, 1939 (April 13, 1937).

Skimming device for glass tanks or furnaces. T. F. PEARSON (Crown Cork & Seal Co., Inc.). U. S. 2,169,429, Aug. 15, 1939 (April 29, 1937).

Spectacle lenses. O. P. RAPHAEL. Brit. 509,954, Aug. 10, 1939 (Aug. 22, 1938).

Telephotographic objective. WILLY MERTÉ (Carl Zeiss). U. S. 2,171,274, Aug. 29, 1939 (June 12, 1937).

Structural Clay Products

Heat-transmission coefficients. A. F. DUFTON. *Jour. Inst. Heating & Ventilating Eng.*, **7** [77] 221–45 (1939).—D. gives a review of the variations which cause considerable changes in the conventional figures. The discussion includes a summary of the contents of a preliminary code (to be used after July 1, 1940) which contains heat-transmission figures and physical properties of the materials used in the building trade. See *Ceram. Abs.*, **18** [10] 269 (1939). J.M.N.

Lightweight aggregates offer possibilities as a side line. ANON. *Concrete, Cement Mill Ed.*, **47**, 192 (1939).—Analysis of burned Haydite clinker shows a chemical composition close to seven shales and clays used by cement plants scattered over the United States. At present

most of the Haydite is made by clay brick manufacturers; none is made by the cement manufacturers. W.D.F.

Linear shrinkage of pugged clays. H. H. MACEY AND F. G. WILDE. *Bull. Brit. Refrac. Research Assn.*, No. 41 (Sept., 1936); reprinted in *Trans. Brit. Ceram. Soc.*, **38** [5] 331–39 (1939).—Numerous experiments on the effect of stress during drying on the linear shrinkage of pugged clay specimens led to the conclusion that the orientation of the clay particles, which is responsible for the difference in shrinkage along different axes, takes place in the barrel of the pug where the clay is in comparatively violent motion, and it is not appreciably affected by the pug mouthpiece. R.A.H.

Progress in prestressing structural clay masonry. F. O. ANDEREGG. *Bull. Amer. Ceram. Soc.*, **18** [9] 323–25 (1939).

Use of lime in the production of clay brick. P. F. ZANKO. *Stroitel. Materialy*, **1938**, No. 10–11, pp. 31–32. —"Vaccillating" clays can be improved by adding slaked lime, which contributes to the aggregation of fine clay particles. P.B. & E.S.

PATENTS

Brick-cleaning machine. E. C. COUSART (Clyde A. Luck, C. S. Cowan, and N. T. Williams). U. S. 2,170,783, Aug. 22, 1939 (June 21, 1938).

Brick grab. J. P. CALLAGHAN (Paul Gabriel Corp.). U. S. 2,170,706, Aug. 22, 1939 (Jan. 26, 1938).

Building construction. J. C. P. LEEMHUIS (Harry Schoenhaut). U. S. 2,171,001, Aug. 29, 1939 (Dec. 24, 1936).—A hollow floor or roof structure includes a series of lower beams supported at their extremities and having upper and lower flanges and a series of upper beams resting upon the lower beams and having upper and lower flanges, each of the lower beams having secured thereto at least one transverse rib which engages an adjacent one of the upper beams between the flanges thereof and so locks the adjacent upper and lower beams together in the direction of their load.

Double plates made of rolled clay in the form of hollow brick. C. BAUCARNAUD. Fr. 847,341, Oct. 28, 1938. D.A.B.

Refractories

Aluminum industry of Italy. ROBERT J. ANDERSON. *Mining Mag.*, **61**, 13–27 (1939).—Total reserves amount to 34 million tons of bauxite, but only about one-third is suitable for the Bayer process. There are enormous deposits of leucite-bearing rocks which have been used, but so far this has been uneconomical. Cryolite is made artificially, using fluorite found in Italy. The aluminum industry is one of the major consumers of electric power, most of which is from hydroelectric plants. The aluminum producers made 23,000 tons of the metal in 1937 and mined 370,000 tons of bauxite. W.D.F.

Assessing the stability of refractory structures. DANIEL PETIT. *Trans. Brit. Ceram. Soc.*, **38** [5] 313–30 (1939).—P. attempts to describe a method of assessing, or at least determining with some degree of accuracy, the conditions under which the refractories are used in a given installation or the nature of the properties of the materials to be used in any given case. Taking into account the refractoriness of the products, the method provides means of determining either the maximum temperature at which an existing installation may be operated without risk or the conditions under which a new installation ought to be constructed to function at a given temperature. If a refractory material is subjected to the refractoriness test under a constant load and rising temperature, but under various different loads, curves are obtained which differ considerably. If the geometric locus of the temperatures corresponding to the degrees of subsidence of the samples under varying loads is established, plotting temperatures as abscissas and loads as ordinates, a series of curves is obtained. These curves form a sort of fan converging to a point at zero load. This point corresponds to softening conditions under zero load and is known as the "fusion point." In considering the diagrams, P. concludes that if refractory products are used under such conditions of temperature and pressure that the point of intersection of the vertical and horizontal lines corresponding to these temperatures falls to the left of the line "commencement of subsidence," the material will be resistant. If the point falls to the right of the line, the material will be in the danger zone. See "Resistance—," *Ceram. Abs.*, **18** [7] 184 (1939); "Method—," *ibid.*, [8] 213. R.A.H.

Bauxite cement. GOPAL CHATTERJEE. *Indian Ceramics*, **1** [1] 20–21; [2] 52–54 (1938).—Natural bauxite is found in abundant quantity in many parts of India. J. C. Roy Chowdhury produced bauxite cement of remarkable strength by subjecting a mixture of lime and ground ferruginous bauxite to a pressure of 800 lb. and then calcining or sintering. His process is based on the discovery that intimate chemical combination of lime with alumina or bauxite takes place at a low temperature, viz., below 1100°C, in an ordinary furnace or kiln. The process has the following advantages: (1) capital cost is low because no expensive rotary kilns are required for vitrification of the Portland cement mixture and no high-efficiency blast or electric furnaces are required for fusion of the lime-bauxite mixture; (2) the unit may be as low as 10 tons per day or 3000 tons a year; (3) steam coal may be used instead of hard coke; (4) impure bauxite or laterite which is available in many places in Bihar and Central Provinces can be used; and (5) unskilled or semiskilled labor only is used. The properties and uses of bauxite cement are also discussed. A.P.S.

Chemical analyses of sintered magnesite. V. RODT. *Chem.-Ztg.*, **63** [46] 404–405 (1939).—Sintered magnesite is falsely called magnesite (the name intended for natural $MgCO_3$) in the commercial world. This sintered magnesite contains certain impurities such as silicon dioxide, aluminum oxide, and iron oxide, and this necessitates analyses of the product. A detailed method of analysis is given by R. for determining the constituents of sintered magnesite. D.A.B.

Control basic open-hearth practice. JOHN W. PORTER. *Foundry*, **65** [11] 29–30, 86, 90 (1937).—The building of a magnesite open-hearth bottom is described in detail. Illustrated. See "Open-hearth—," *Ceram. Abs.*, **18** [1] 23 (1939). F.G.H.

Control of the firing of silica brick. S. G. SYTOV AND A. V. DEMAKOVA. *Ogneupory*, **6** [6] 1294–1302 (1938).—The operation of furnaces firing silica brick and the effect of the temperature and duration of firing on the brick quality were studied at the Mariupol refractory plant. The best results were achieved at temperatures of 1435° to 1460°. M.V.C.

Corrosion phenomena in electrical heating technique. W. HESSENBACH. *Elektrotech. Z.*, **60** [29] 865–70 (1939).—Difficulties caused by corrosion of various ceramic insulation materials and metals used for electrical heating appliances are described. Corrosion is primarily caused by oxide scaling and food remnants. In electrical furnace construction reactions with refractories are a major factor. Some defects are also caused by puncture at high temperatures. Corrosion may also be caused by the action of oxides, salts, and fused metals and attack by gases, especially sulfur. A table of various types of refractories, such as fire-clay, sillimanite, magnesite, SiC, and alundum brick, and their chemical composition is presented. Listed are such properties as heat conductivity, specific resistance, melting (or softening) point, coefficient of expansion (room temperature to 1000°C), etc. Corrosion is shown in a series of illustrations of metal conductors and ceramic insulation materials. L.E.T.

Critical examination of the load test for refractories. F. H. NORTON. *Jour. Amer. Ceram. Soc.*, **22** [10] 334–36 (1939).

Degree of dispersion of the fluxing material affects the sintering and fusing range. T. SCHAUER. *Sprechsaal*, **72** [29] 378–79 (1939).—Resistance to temperature change is

one of the most difficult requirements of refractory building materials to fulfill. Good clays for grog ware resistant to temperature change are the Palatinate (Pfälzer) crucible clay, electrically fused magnesite, and chrome ore. S. studied the effect of different kinds of dispersion of the sintering agents (Fe_2O_3 and SiO_2) in Palatinate crucible clay in its sintering range (beginning of sintering and end of softening under load). The results were as follows: (1) the type of dispersion has a great effect on the sintering and fusing range; (2) the fusing range in refractory building materials can be increased by the addition of very finely divided flux (best in solution), without appreciably affecting the refractoriness; (3) it is not the amount (percentage) of the fluxing agent which is decisive for the fusing range but the state of its dispersion; (4) by finer preparation it must also be possible to obtain crucible clay resistant to temperature change from other deposits similar to the grog crucible clay; (5) the sintering range is increased in refractory building materials with low flux content by the finest possible division of the flux; (6) an increased fusing range can be obtained for easily fusible glasses and enamels by mixing them with more difficultly fusible glass and materials (preferably coarse-grained).
M.V.C.

Dewatering of bauxite on the charging floor of electric furnaces used for the production of corundum. M. V. KAMENTSEV. *Tsvetnye Metally*, **14** [7] 106–14 (1939).—Most of the moisture of the bauxite was eliminated in the upper layer of the charge or on the charging floor by the heat of the combustion gases. The chemically bound water is eliminated at short distances from the melt, resulting in increased consumption of electric energy as well as in imperfect operating conditions. On the basis of this investigation, K. concludes that calcination of the bauxite is desirable but that drying of the bauxite is not desirable at all.
B.Z.K.

Durability of stoppers at the electrical steel-melting plant No. 1 of the Zaporozhstal works. S. N. BELORUSOV. *Ogneupory*, **6** [7] 1323–27 (1938).—On the whole, silicon carbide, highly aluminous, and andalusite stoppers are of equal value. The basic factor which characterizes the durability of stoppers is not the material but its density and structure.
M.V.C.

Effect of fluxes on the refractoriness of refractory materials. MARCEL LÉPINGLE. *Céram., Verrerie, Email.*, **6** [12] 361–67 (1938); **7** [1] 5–11; [3] 87–89; [4] 119–22; [5] 155–58; [6] 189–92 (1939).—L. presents a theoretical consideration of the binary systems SiO_2–Al_2O_3, SiO_2–MgO, and Al_2O_3–MgO, the ternary systems SiO_2–Al_2O_3–CaO and SiO_2–Al_2O_3–MgO, and their diagrams of fusion. The fusing temperature of Seger cones, which are an example of the effect of fluxes on ceramic masses, is calculated. The fusion of ceramic masses follows the laws of heterogeneous equilibrium which is governed by the law of phases. If the fusion equilibriums are known theoretically for a certain number of cases, it is necessary in practice to take into account the complexity of mixes. The stable compounds, their combinations, their stability, and the eutectics can be fixed only by many practical determinations. In practice the determination of the temperature of Seger fusion depends on the medium (oxidizing or reducing), the fineness of grinding, and the rate of heating. Increasing fusibility and the attack by fluxes and slags were studied. The examination of fusion diagrams of the systems $Al_2O_3 + SiO_2 + CaO$ and $Al_2O_3 + SiO_2 + MgO$ permits an approximation of the influence which the introduction of a flux into elementary mixes could have on the temperature. It is difficult to calculate beforehand what the action of a flux will be; it depends on the composition, temperature, and the characteristics of the brick or grog. An increase in the alumina content often favors the resistance to the action of fluxes. The effect of fluxes on the softening temperature is discussed. Tests were made on a silicoaluminous grog with varying additions and kinds of flux (dry sodium carbonate, commercial sol, plaster, precipitated magnesia treated with HCl, and cement with oxychloride and sexioxide of iron). Tests to ascertain the effect of wood and coal ash on different kinds of refractory masonry and the results obtained are described. Specimens of carbographite and crystallized silicon carbide were superior to silicoaluminous products and other special refractories examined in these tests. Among the silicoaluminous brick, two specimens of Czechoslovakian brick gave satisfactory results, probably because they were made from kaolinic clays free from organic matter which produces permanent porosity in the grog when fired. This specific porosity of grog favors the penetration of fluxes probably by either capillarity or variations in surface tension. Extra-aluminous, mullitic, or corundum products gave no useful results under the conditions studied. Silicon carbide brick may be used only in the most exposed zones because of their high cost; other parts of the masonry can be lined with silicoaluminous brick. Care must be exercised in the choice of quality and method of manufacturing of refractory products because new processes are still in a more or less experimental stage.
M.V.C.

Effect of hydrocarbon gases on refractory materials: II–III. E. ROWDEN AND A. T. GREEN. *Bull. Brit. Refrac. Research Assn.*, No. 39 (April, 1936); reprinted in *Trans. Brit. Ceram. Soc.*, **38** [7] 418–34 (1939); see *Ceram. Abs.*, **16** [5] 150 (1937).
R.A.H.

Engobed ladles. K. I. SHARONOV. *Ogneupory*, **6** [6] 1273–77 (1938).—Attempts to use engobed grog ladles for casting steel are briefly discussed. The engobing of steel-casting ladles considerably increased their durability and prevented the corrosion of the ladles by the metal.
M.V.C.

Evaluation of the squatting temperatures of cones used for the determination of refractoriness. VAUGHAN H. STOTT. *Trans. Brit. Ceram. Soc.*, **38** [6] 341–58 (1939).—The National Physical Laboratory investigated the problem of testing English Seger cones 26 to 35. It is possible to determine with sufficient accuracy the squatting points of these cones under suitable working conditions, but the cost is high. The variations between cones of the same batch are small, and it is therefore feasible to test a few cones from a large batch and to use the remainder as secondary standards with which other cones may be compared.
R.A.H.

Expansion of fired silica brick. I. S. KAĬNARSKIĬ AND V. A. BRON. *Ogneupory*, **6** [9] 1413–24 (1938).—The effect of a series of production factors on the expansion of raw silica on firing was studied. These factors may be regulated during manufacture; a rational correlation of these factors will minimize the defects inherent in the property of raw silica of expanding on firing because of the transformation of quartz. The effect of the introduction of mineralizers, crushed fired silica, different quartzite batches, the velocity of rising temperature, and the character of furnace atmosphere were studied. Mineralizers should be used only in cases where the maximum refractoriness of silica is not required. Raw silica from coarse-grained mixes requires a retarded rate of increase in temperature beginning with 1150°. The composition of batches containing quartzites with different properties (soft and hard cement quartzites and mixtures of crystalline quartzites) is very important since it affects the thermal stability of raw materials on firing and allows the use of rapidly transforming quartzites. See *Ceram. Abs.*, **18** [5] 129 (1939).
M.V.C.

Foundry refractories. W. J. REES. *Foundry Trade Jour.*, **59** [1154] 239–40 (1938).—The properties of cupola ganisters and siliceous ramming mixes are discussed. The changes in the crystal form of the various forms of silica are pointed out with their accompanying change in volume. If reasonably pure quartz is gradually heated to 575°C it changes from the alpha to the beta form. If the heating is continued, the beta-quartz may change into tridymite or may remain in a metastable condition until a temperature of about 1200°C when, instead of changing to tridymite, it changes into cristobalite. Whether the change is to tridymite or, at a higher temperature, to cristobalite depends upon whether there are any melt-forming impurities or "melt" formed from additions to the silica (such as bond or impurities) which will facilitate the

change to tridymite. The change of quartz directly to cristobalite is a dry change, while the change from quartz to tridymite is a wet change. The cupola lining material should ram easily, give a product of high density, and sinter uniformly and easily. H.E.S.

Investigation of certain properties of refractory concrete. R. T. GILES. *Bull. Amer. Ceram. Soc.*, **18** [9] 326–32 (1939).

Iron oxide content of open-hearth steel as a function of the basicity and oxidizing ability of the slag. P. N. IVANOV. *Metallurg*, **13** [4] 21–30 (1938).—Open-hearth steels smelted with highly basic slags were analyzed for their FeO contents. The results showed that, contrary to the widespread views concerning the oxidizing influence of slags upon the FeO in the metal, the FeO content was large. The FeO content increased with increasing basicity of the slag, but it increased more rapidly than the ratio of CaO/SiO_2. The increase in FeO is due to two factors: (1) an increase in the partial pressure of CO dissolved in the metal and (2) a decrease in the Mn content in the metal. Both factors are the result of the increased viscosity of the slags. The disparity between the theoretical predictions and the experimental data is due to the fact that the theories deal with the extraequilibrium concentration of dissolved FeO. Due to the high speed of the reaction in the homogeneous liquid phase, the extra-equilibrium concentration of FeO cannot be fixed, and it has no practical effect upon the quality of the steel. The equilibrium concentration, which is determined analytically and which affects the quality of the steel, increases with increasing basicity. It is practically impossible to eliminate the harmful effects of the highly basic slags because they are due to the high viscosity which is characteristic of such slags. The production of high-quality steel requires the use of slags of lower basicity (CaO/SiO_2 = 1.8 to 2.0). In using such slags, the difficult elimination of P and S may be partly compensated by employing bauxite which will increase their fluidity and basicity. B.Z.K.

Laboratory slagging-test furnace with a rotating burner. R. K. HURSH. *Jour. Amer. Ceram. Soc.*, **22** [10] 354–57 (1939).

Measuring the expansion of silicoaluminous refractories: sillimanite brick. MARCEL LÉPINGLE. *Compt. Rend. 18me Congr. Chim. Ind.*, **1938**, 238–50; *Chem. Abs.*, **33**, 6549 (1939).—Numerous analytical data relative to mullitic refractories are given in tabular and graphic forms. Results obtained by the Chevenard dilatometer showed that in many cases the transformation point of quartz was apparent; this could not logically be expected. No relationship seems to exist between expansion and resistance to variations in temperature.

Melting nonferrous alloys. N. K. B. PATCH. *Foundry*, **66** [4] 33–34, 82 (1938).—P. discusses the factors which affect the selection of crucibles for melting nonferrous alloys in the pit-type furnace. Illustrated. F.G.H.

Melting nonferrous metals. N. K. B. PATCH. *Foundry*, **66** [5] 71, 138 (1938).—P. discusses the selection of burners for use in the combustion of various types of fuels. The selection, installation, and maintenance of refractories in various types of melting equipment are also discussed. *Ibid.*, [6] 34, 108.—Several reverberatory or barrel types of melting furnaces and the installation of both brick and monolithic linings in these furnaces are discussed. *Ibid.*, [7] 28, 77.—The installation and maintenance of monolithic linings in cylindrical reverberatory furnaces are described in detail. Methods of keeping refractory costs are also discussed. Illustrated. F.G.H.

Monolithic floors of tunnel-kiln cars from refractory concrete. S. V. GLEBOV AND E. A. GERMAN. *Ogneupory*, **6** [7] 1274–86 (1938).—Experiments showed that monolithic floors made from 80% crushed brick and 20% (by volume) of aluminous cement were satisfactory for cars used in tunnel kilns for firing brick and grog products. See *Ceram. Abs.*, **18** [4] 109 (1939). M.V.C.

Observations on the slagging of some glass furnace checkers. W. L. FABIANIC. *Jour. Amer. Ceram. Soc.*, **22** [10] 337–42 (1939).

Obtaining aluminum oxide from the product of sintering sodium sulfate with kaolin. YA. A. FIALKOV AND S. D. SHARGORODSKIĬ. *Zapiski Inst. Khem., Ukrain. Akad. Nauk*, **5**, 487–505 (1938).—Experiments were conducted to extract Al_2O_3 from the product of sintering sodium sulfate with kaolin. Na_2SO_4 and kaolin (1:1) and 0.9 gram atom of C were calcined for 1 hr. at 1100° to 1200°. The product obtained had the following composition: SiO_2 39.83, Al_2O_3 37.65, Fe_2O_3 1.50, CaO + MgO 1.24, Na_2SO_4 7.11, and Na_2O 12.67%. Both acid and alkaline methods of extracting the Al_2O_3 were tried. In the former, the product was treated by boiling for 1 hr. with H_2SO_4 and HNO_3 of various concentrations. Results show that 5 to 7% acid solutions give an extraction of 80% Al_2O_3 along with considerable amounts of SiO_2 and Fe_2O_3. The iron can be eliminated by means of $K_4Fe(CN)_6$ and $K_3Fe(CN)_6$ followed by a treatment of *siestoff* which is prepared by boiling kaolin with a 4 to 5% solution of H_2SO_4 and then washing out the SiO_2. To find a method of extracting the Al_2O_3 from the solutions, experiments were conducted to establish the thermal decomposition of $NaNO_3$ in the presence of Al_2O_3 or $Al(NO)_3$. The results, given in curves, indicate that the aluminate starts to form above 600° and that the reaction is most intense at 700° to 750°. In the alkaline method of extracting, the product was calcined for 1 to 2 hr. in a Pt electric oven at 1100° with a mixture of soda and $CaCO_3$. Ratios of Na_2CO_3/Al_2O_3 and $CaCO_3/SiO_2$ varied from 1:1 to 2:1. The resulting product was boiled with water and filtered. Tests of the filtrates showed a possible extraction of 70 to 80% Al_2O_3. No iron was found. See "Thermal—," *Ceram. Abs.*, **16** [3] 102 (1937). B.Z.K.

Operates cupola for 120 hours before dropping bottom. JOHN SONNENFELD. *Foundry*, **67** [5] 100 (1939).—A $4^1/_2$-in. silica brick lining is used in a water-jacketed cupola which delivers 7 tons of iron per hour to mechanical puddlers at temperatures between 2600° and 2700°F in 7000-lb. lots every 30 min. Every 4-hr. melting is suspended for 1 hr. while bottoms in the mechanical puddlers are repaired. After 120 hr. of operation, the cupola bottom is dropped and the lining in the melting zone above the tuyères is replaced. In this zone, the silica-brick lining varies from 2 to 4 in. in thickness after 120 hr. of operation. Illustrated. F.G.H.

Operating a cupola. H. W. KELLY. *Foundry*, **65** [12] 37, 86 (1937).—Methods of installing refractory linings are described and illustrated. F.G.H.

Possible causes of damage to electric furnaces. E. OROSCO. *Rev. Chim. Ind.* [Rio de Janeiro], **8**, 170–72 (1939); *Brit. Chem. & Phys. Abs.–B*, **58** [7] 739 (1939).—Magnesite brick from damaged furnaces were deficient in MgO.

Preparation of crucibles from special refractories by slip casting. JOHN G. THOMPSON AND MANLEY W. MALLETT. *Jour. Research Nat. Bur. Standards*, **23** [2] 319–27 (1939); R.P. 1236. Price 10¢.—Beryllia crucibles with uniform thin walls, smooth inner surfaces, and capacities up to 300 $cm.^3$ were prepared by a slip-casting process. The necessary plasticity for slip casting was developed in calcined, finely ground beryllia by treatment with diluted hydrochloric acid at room temperature. Good castings were obtained from suspensions of the acid-treated beryllia in diluted hydrochloric acid, but equally good castings and longer life of the plaster molds were obtained when the diluted acid of the casting slip was replaced with water. The slip-casting process developed for beryllia was also used for the preparation of crucibles of alumina, thoria, zircon, and zirconia. Slip-cast crucibles had wall thicknesses of about 3 mm., but brick 5 cm. in thickness were prepared by a modification of the slip-casting process. Crucibles of magnesia, which could not be cast from aqueous slips, were cast from suspensions of magnesia in absolute alcohol. R.A.H.

Pressed multigrog brick. S. V. GLEBOV AND A. K. KARKLIT. *Ogneupory*, **6** [8] 1360–66 (1938).—Experiments were made on the production of multigrog brick by the semidry method. Such brick of great density and

correct shape and size possess a high mechanical stability reaching beyond 500 kg./sq. cm. and are excellent refractories for large blast furnaces. M.V.C.

Production of alumina from South Ural bauxite by the wet method of sintering. K. E. MANOILOV. *Tsvetnye Metally*, **14** [6] 103–106 (1939).—South Ural bauxite, containing Al_2O_3 56.4, Fe_2O_3 21.6, SiO_2 4.6, TiO_2 2.5, and moisture 3.4%, was mixed with limestone (52.7% CaO) to give a ratio of CaO/SiO_2 2 and with dry calcined soda to give a ratio of $Na_2O/(Al_2O_3\ Fe_2O_3)$ 1.02 and then sintered by the wet method for 35 to 45 min. at 1150° to 1180°. The sintered product contained Al_2O_3 39.9 to 40.3, Fe_2O_3 14.0 to 14.2, SiO_2 3.5 to 3.6, CaO 6.2 to 6.4, TiO_2 1.8 to 1.9, and Na_2O 29.8%. The product was leached in diffusers. The extraction of Al_2O_3 was 95.75%, and that of Na_2O was 95.2%. Calcination of the sintered product at 1200°, 1250°, and 1300° did not increase the amount of soluble Al_2O_3 in the product. Experiments were also conducted by sintering a mixture of South Ural and Tikhvin bauxite in the ratio of 1:1. The Tikhvin bauxite contained Al_2O_3 47.3, Fe_2O_3 16.6, and SiO_2 12.7%. The extraction of bauxite was 93%. B.Z.K.

Production of refractories based on Novoselitza secondary kaolins. A. I. KRAMARENKO. *Ogneupory*, **6** [9] 1425–30 (1938).—Temperatures of over 1400° are found in furnaces firing coal dust, and the refractories used show layerlike cracks. Refractories containing secondary kaolins are more stable under such conditions. The refractories show high indices of refractoriness and thermal stability when containing about 40% alumina. Such refractories are the most suitable for furnaces firing coal dust. M.V.C.

Properties of air-setting refractory-bonding mortars of the wet type. RAYMOND A. HEINDL AND WILLIAM L. PENDERGAST. *Jour. Research Nat. Bur. Standards*, **23** [1] 7–38 (1939); R.P. 1219. Price 10¢.—Twenty air-setting mortars, furnished by twenty manufacturers, were subjected to a series of tests, both without the addition of water (troweling consistency) and with the addition of water (dipping consistency), to obtain information suitable for preparing a Federal specification covering this commodity. The condition of the different mortars, after being in storage for varying periods up to 33 months, was judged by the relative ease with which they could be removed from the container and with which the segregated liquid and solids could be recombined. Five of the 20 mortars, in storage from 9 to 17 months, had settled to such an extent that remixing them in a mortar box would not have been feasible. After they were remixed, the troweling consistency of 12 mortars was good, 7 fair, and 1 poor. The loss of moisture at 105°C, based on the dry weight of the mortar, ranged from 20.6% to 32.8%. The amount of water in the mortars when in a dipping consistency ranged from 26.9% to 51.0%. The residue retained on a No. 40 U. S. Standard sieve was 1% or less for 15 of the mortars, and for all the mortars, the residue on a No. 100 sieve ranged from 0 to 35%. The alkali content, expressed as sodium oxide, ranged from 1.22% to 3.40%. The pyrometric cone equivalents of the mortars were 14 to 37. There was very little difference in pyrometric cone equivalents between the calcined and uncalcined mortars, although in some cases the end points of the uncalcined materials were much more difficult to obtain. A mechanical device was used to classify the mortars in regard to the comparative ease with which they could be spread or troweled on fire-clay brick. Four tests were made in which both the number of strokes of the trowel and the final thickness of the mortar layer were varied. Six mortars rated "very good" in all tests, one rated "good" in all tests, and the remainder rated from "very good" through "fair" and "poor," the ratings varying with the individual tests. After drying on the brick, the mortars were rated on their tendency to curl and to crack as follows: "no," "slightly," "moderately," or "badly." Four of the six mortars which rated "very good" in the troweling test showed no cracking or curling on drying. None of the mortars were rated "badly" in both respects, but five rated as such in either one or the other. The average transverse strengths of the air-set neat mortars ranged from 685 to 6470 lb. per in.^{2}. The strength of the test bars was greater in many cases when the surface uppermost during drying was in tension in the breaking test. This effect was caused probably by the concentration of alkali salts (due to migration) near this surface. The change in strengths of the mortars resulting from heating at various temperatures up to 1350°C and cooling varied with the materials. According to such change in strengths the mortars could be classed as follows: (1) those of high air-setting strength, which was lowered by heating at intermediate temperatures but raised again, probably because of vitrification, when heated at the highest temperatures; (2) those of high air-setting strength, which was lowered by heating at intermediate temperatures and not further changed by heating, even at the highest temperatures; and (3) those of comparatively low air-setting strength, which changed very little with heating at the lower range of temperatures but increased progressively with heating at moderately higher and the highest temperatures. Most of the mortars were of the first two types. Although not all mortars reached their lowest strengths after being heated at 750°C and cooled, such strengths were, in general, close to the lowest obtained after they were heated over a fairly wide range of temperatures. The time required for the mortars to air-set, as indicated by their resistance to flow under load, ranged from 1 to 90 min. when used to bond firebrick of 8.6% absorption. Eight mortars set within 1 min., and an additional six set within 3 min. The bonding strength of the mortars in assemblages of two half-brick and mortar was obtained. These assemblages were heated at the same temperatures at which specimens from the neat mortars had been heated. The lowest strength was 5 lb. per in.^{2} and the highest was 540 lb. per in.^{2}. In general, a high air-setting strength of the neat mortar presages a satisfactory strength of a brick-and-mortar assembly in cross bending. Failure of the assembly occurred either in the brick, in the mortar, in the joint, or in some combination of these. Piers of two standard-size brick and two half-brick (making one vertical and two horizontal joints) were made up with $^1/_8$-in. and $^1/_{16}$-in. joints. After drying, none of the joints showed serious cracking, but after they were heated at 750°C, four were badly cracked. During the heating at 1425°C many of the cracks visible before the heat treatment healed, but numerous cases of thermal cracking occurred. Heating at 1500°C caused slippage of the brick in the case of three mortars. The appearance of five mortars was much better in units made with the $^1/_{16}$-in. joint than in those made with the $^1/_8$-in. joint. Four mortars were practically free from defects in either size joint. Examination of the mortars after heating at 1425°C and 1500°C in fusion-test blocks gave information relative to shrinkage, cracking, migration of salts, and flow because of fusion. This information was in good agreement with observations made on piers of two whole and two half-brick and mortar heated similarly. The results lead to the conclusion that a specification governing air-setting refractory mortars may be prepared with the assurance that a satisfactory commercial product may be obtained readily in the open market. R.A.H.

Refractories for methane-cracking plants. A. K. KARKLIT. *Ogneupory*, **6** [9] 1449–54 (1938).—The conversion of methane with water steam requires refractories (for lining converters) which will withstand a gaseous atmosphere containing H_2O, H_2, and CO at high temperature. Experiments showed that this gaseous atmosphere excludes the use of carbonaceous refractories. At 1300° to 1500°, such gaseous atmosphere does not affect aluminous (grog), silica, magnesite, andchrome-magnesiterefractories. The first two refractories seem to be more suitable. The low thermal stability of silica, however, may be injurious because of the heating and cooling of the converters with changes of temperature. Experimental bodies containing kaolin and corundum may be suitable for lining converters. M.V.C.

Refractories in nonferrous metallurgical furnaces. J. SPOTTS MCDOWELL. *Mining Congr. Jour.*, **25** [5] 17–20

(1939).—Fire-clay brick, de-aired and extruded, is used in the center walls of zinc distillation furnaces; the vacuum-pressed brick is used in open-hearth nickel furnaces and where fluxes are not to be absorbed. Superduty fire-clay brick approach pure kaolin in composition and are used in many places. High-alumina brick is usually made with diaspore clay, blended if necessary with other clay to obtain the desired alumina content. Alumina brick (50%) are used in roaster hearths; 60% alumina brick are used in the side walls of nickel anode furnaces, and 70% alumina brick are used in various lead furnaces. Silica brick are now manufactured with a power press and are much less porous. They are used in copper and nickel reverberatory furnaces. Magnesite brick are bonded by firing and bonded chemically. High-magnesia brick, bonded by firing, are used in the bottoms of copper furnaces and various lead furnaces. Chemically bonded brick in use approach the characteristics of brick bonded by firing. They are used either alone in some copper and nickel reverberatory furnace roofs or only in the hot end, with the rest forsterite or silica. Forsterite brick in the roofs of some copper furnaces has lasted for three years, compared with several months for silica brick. Chrome brick are being used in the upper side walls of brass furnaces. Insulating refractory brick are new and can be used in contact with clean gases or as a backing; they are used in some copper furnaces. W.D.F.

Refractories and thermal shock. J. F. HYSLOP. *Trans. Brit. Ceram. Soc.*, **38** [5] 304–12 (1939); see *Ceram. Abs.*, **18** [3] 76 (1939). R.A.H.

Refractory brick; their manufacture, properties, and applicability in the metal industries. J. KRATZERT. *Elektrowärme*, **9** [6] 117–27 (1939).—Refractories are grouped into the following principal types:

	Material	Part of production (%)	Raw material	Melting point: Seger cone	Melting point: (°C)	Firing temperature: Seger cone	Firing temperature: (°C)
Oxidic	Silica	About 30	Quartzite	32–34	1700–1750	14–18	1400–1500
	Fire clay	About 60	Clay	26–35	1600–1770	10–16	1300–1450
	Mullite	About 10	Kyanite	>36	>1800	14–18	1400–1500
	High alumina		Bauxite-corundum	>36	>1800	14–18	1400–1500
	Magnesite		Magnesite	>42	>2000	16–20	1450–1550
	Chromite		Chrome ores	>42	>2000	14–18	1400–1500
	Chrome-magnesite		Magnesite and chrome ore	>42	>2000	16–26	1450–1600
	Spinel		$RO \cdot R_2O_3$	>36	>1800	>16	>1450
	Zirconium		Zirconium ore	>42	>2000	>14	>1400
	Carbon		Coke	>42	>2000	about 1000	
	Carbides (SiC)		Silicon carbide	>42	>2000	12–16	1350–1450
	Nitrides, etc.			>42	>2000		

All refractories are mixtures, never definite single substances. The silica group consists of at least 95% SiO_2; lime is used as binder. The pure clay substance, the molecule $2H_2O \cdot Al_2O_3 \cdot 2SiO_2$, transforms at 500°C into a water-free compound and disintegrates at higher temperatures into SiO_2 and Al_2O_3; at still higher temperatures, a new stable molecule, mullite, is formed. Kyanite and sillimanite are raw materials of $Al_2O_3 \cdot SiO_2$; kyanite disintegrates at 1300°C, forming mullite also. Magnesite and chromite are composed of 85 to 92% MgO or 30 to 50% Cr_2O_3 with SiO_2, Al_2O_3, FeO, Fe_2O_3, and CaO in varying proportions. Behavior in service, structure, and mechanical properties are discussed at length, and the reactions taking place in service and leading to destruction are described. Brick are destroyed not only by liquid slag but also by gases. Fe-containing materials are affected by CO at 400° to 500°C, when the gas disintegrates under the catalytic action of Fe_2O_3 and C is deposited in the interior of the brick, leading to destruction. Alternating reducing and oxidizing atmospheres have a harmful effect on Cr ore-containing materials above 1000°; the brick become brittle and fall apart; the structure is destroyed, as Cr_2O_3 is not stable at these temperatures. SiC-containing materials are destroyed in oxidizing atmospheres above 1300°C. Gaseous alkalis reduce the refractoriness. The resistance to temperature fluctuations is increased considerably by keeping the elasticity modulus low (fire clay and magnesite). The proper selection of a material for a given purpose is important; directions for selection are discussed, and details of construction for the best utilization of a material are described. M.H.

Refractory concrete for furnace construction. LOUIS LONGCHAMBON. *Compt. Rend. 18me Congr. Chim. Ind.*, **1938**, 970–75; *Chem. Abs.*, **33**, 6549 (1939).—Refractory concrete made of a mixture of fused cement ($CaO \cdot Al_2O_3$) and of crushed refractories can be used without preliminary burning. They withstand temperature variations well and can be used in monoliths of larger dimensions than ordinary refractories. They have poor resistance to fused slag, particularly to siliceous clinkers. Industrial tests have shown that they can be used up to 1400°.

Refractory concretes. A. I. ROÍZEN. *Ukrain. Nauch.-Issledovatel. Inst. Ogneuporov & Kislotouporov*, No. 44, pp. 115–18 (1938).—Cement from slag (from firing bauxites) composed essentially of calcium aluminates and chromite as filler will yield highly refractory and slag-resistant concrete; raw chromite ore or fired chromite may be used. M.V.C.

Refractory materials. J. W. MELLOR AND A. T. GREEN. *Chem. & Ind.*, **57** [27] 627–37 (1938).—Fire clays and the products made from them may be divided into three classes, viz., normal, aluminous, and siliceous. The alumina content of an aluminous firebrick is 40% or more. The silica content of a siliceous firebrick is usually over 72%. A firebrick is essentially a vitrified product which may contain the crystalline substances mullite, quartz, and cristobalite in varying quantities. A well-fired lime-bonded silica brick contains cristobalite, tridymite, and quartz, together with 5 to 10% of a glassy matrix. Magnesite brick vary in constitution of the finished product depending on the firing treatment. The rounded crystals of periclase are usually separated from each other by a silicate bond. The afterexpansion of silica brick and the contraction of fire clay are discussed. There are many aspects of the mechanical properties of silica and fire-clay products at high temperatures which have received little or no attention. Stability at high temperatures has been investigated from the standpoint of one test. Its broader and more fundamental significance calls for considerable study. The reversible thermal expansion of the product is an important factor in the conception of spalling. The temperature diffusivity and elasticity are other factors. The irregular coefficient of expansion of all refractories containing appreciable quantities of free silica is due to the presence of quartz, cristobalite, and tridymite. Slag attack can be divided into corrosive and erosive types, the latter playing the more important part in most cases. Factors governing slagging are (1) the rate of formation

and removal of the product formed by the corrosive action; (2) the rate at which the flux is supplied and, in some cases, the velocity of the gases bringing the slagging agents to the refractory surface; and (3) the nature of the refractory. A fundamental approach to the study of slag action includes investigation of (1) the reactivity between the slag or slag-forming substances and the refractory, (2) the physical properties of the original slag and of the substance formed by the slags, and (3) the penetrability of the refractory to the slags. The action of CO and certain hydrocarbons proves fatal to refractories containing iron oxide, but when ferruginous material in the form of complex silicates is encountered there is no action. Volatilization of alkali salts may have a very deleterious effect on refractories. KCl vapor in a dry atmosphere reacts more rapidly with fire-clay products than with silica, but in a moist atmosphere the reverse is true. Chlorine or HCl passed over firebrick at 1100° can induce volatilization not only of iron but also of lime, magnesia, alumina, and titania. Investigations on the durability of firebrick in blast-furnace linings and of silica brick in continuous vertical gas retorts show the zonal effects in these installations. The properties of jointing cements require careful control. The chief deficiencies of such cements are (1) inadequate refractoriness, (2) excessive contraction on drying and heating to working temperature, (3) excessive expansion in use at working temperature, and (4) inadequate bonding power. Some modern trends indicate that the texture of fire-clay products is influenced by all the processes of manufacture. Grain size of the clay, the nature, amount, and grading of the grog, and the firing operation are perhaps the most important factors of texture. The production of unfired refractories and of fused alumina, magnesia, silica, and "electrocast" refractories is briefly treated. G.R.S.

Refractory products. R. LEDUC. *Argile*, No. 195, p. 19; No. 196, pp. 13–17 (1939).—A refractory product must be resistant to a temperature of 1580° or above (cone 26) and to physical, chemical, and dynamic influences produced in it by the temperature. Some artificial or natural products with resistance to temperatures lower than 1580° may be used in some cases. Refractory clays used in the production of refractory products are formed by the decomposition of feldspathic rock (kaolinization). This phenomenon is brought about by the action of atmospheric agents (water, carbonic gas, freezing, and heat) and the resulting chemical reactions and forms a hydrated aluminum silicate with small quantities of alkalis, magnesia, lime, iron oxide, free silica, titanic anhydride, and sometimes manganese and vanadium; organic matter also is sometimes present. An analysis of French, Belgian, and German clays is presented in tables. See *Ceram. Abs.*, **18** [1] 34 (1939). M.V.C.

Refractory products in kilns and electrical heating apparatus. ANON. *Rev. Chauffage Elec.*, **6** [6–7] 157 (1938).—New refractory products for use in electric furnaces and electric apparatus are Ohmolithe, Clayrithe, Mullerithe, and Montchalithe. M.V.C.

Relation between permeability and porosity of refractories: II. J. G. DE VOOGD AND S. F. BOHLKEN. *Het Gas*, **56**, 90–93 (1936); *Brit. Chem. & Phys. Abs.–B*, **58** [2] 150 (1939).—Tests with brick, clay, and SiO_2 are described. The permeability of SiO_2 brick with porosity (P) less than 25% varied greatly and was independent of P. Above 25% it increased with P. A similar limit for clay brick was P 30%. SiO_2 brick of similar origin and firing varied less than 100% in permeability. Permeability is of importance in ovens in determining resistance to slag attack. For Part I see *Ceram. Abs.*, **15** [11] 336 (1936).

Series iron oxides–lime. WELTON J. CROOK. *Jour. Amer. Ceram. Soc.*, **22** [10] 313–22 (1939).

Series iron oxides–silica. WELTON J. CROOK. *Jour. Amer. Ceram. Soc.*, **22** [10] 322–34 (1939).

Slag-tap saves at St. Croix Paper Co., Woodland, Maine. JOHN T. TOPALOSKY. *Power*, **83** [1] 38–39 (1939).—Plastic chrome ore and chrome-magnesite brick were the most satisfactory refractory materials for service in a slag-tap furnace which burned pulverized coal containing 3.79% sulfur and 15.5% ash. The ash fused at less than 2000°F and became fluid at 2300°F. The chrome-magnesite brick had a fusing temperature of about 2900°F in the presence of the ash and about 3100°F in air. Drawings of the refractory installation are included. F.G.H.

Special shapes increase life of checker-chamber arches. THOMAS B. HART. *Ceram. Ind.*, **29** [2] 124 (1937).—Use of a dry course of checker brick, laid flat on flat-topped checker-chamber rider arches, will materially increase the life of any type of rider arch by protecting it from slag and clinker and will give a smooth, even surface on which to build the checker setting. The use of large special shapes in the arches will materially increase their life, as there are fewer joints which are subject to the attack of slag and clinker and fewer surfaces which are subject to spalling. Illustrated. E.J.V.

Standardize your cupola practice. GARNET P. PHILLIPS. *Foundry*, **66** [3] 34–35, 86, 89 (1938).—Refractories for cupolas and ladles are discussed from the standpoints of chemical composition and physical structure. Illustrated. F.G.H.

Technology of production of high-grade kaolin refractories. E. K. KELER. *Ogneupory*, **6** [8] 1367–73 (1938).—The production of kaolin refractories was improved. The wet or semidry methods of shaping can be used. High-fired or low-fired grog can be used. The firing temperature of kaolin products lies between 1480° and 1520°. Refractories of high thermal resistance and slag resistance, containing from 42 to 45% alumina and having a temperature of incipient deformation under load of 1500° to 1550°, can be produced. M.V.C.

Thermochemistry of North Carolina olivine in the manufacture of forsterite refractories. ROBERT L. STONE. *Jour. Amer. Ceram. Soc.*, **22** [10] 342–48 (1939).

Universal device for testing deformation at high temperature. E. K. KELER. *Ogneupory*, **6** [6] 1284–87 (1938).—A universal device for testing ceramic products for deformation under load, expansion, and bending at high temperature was developed by K. A brief description of the apparatus is given. M.V.C.

X-ray study of aluminosilicate refractories. A. H. JAY. *Trans. Brit. Ceram. Soc.*, **38** [8] 455–63 (1939); see *Ceram. Abs.*, **18** [3] 78 (1939). R.A.H.

BOOK AND SEPARATE PUBLICATION

Open-Hearth Furnace: Vol. II. WILLIAM C. BUELL, JR. Penton Publishing Co., Cleveland. 260 pp. Price $4.00. Reviewed in *Foundry*, **66** [1] 79 (1938).—Refractory requirements for the open-hearth furnace are discussed in detail. For Vol. I see *Ceram. Abs.*, **16** [11] 341 (1937). F.G.H.

Wall and Arch Construction. ANON. *George P. Reintjes Co. Bull.*, No. 301; reviewed in *Foundry*, **66** [9] 94 (1938).—Many illustrations and diagrams show wall construction of tile, brick, and castings and many arches and arch nosing combinations. F.G.H.

PATENTS

Brick for the construction of ceramic furnaces. EMMY FLEISCHER PHILIPP. Ger. 675,269, June 13, 1939 (Oct. 5, 1935); V/36*a*. 13.13. D.A.B.

Corrected basic refractories. E. J. LAVINO & CO. Brit. 510,087, Aug. 10, 1939 (Feb. 10, 1937).

Crucible furnaces. I. HALL. Brit. 511,572, Aug. 30, 1939 (Feb. 18, 1938).

Furnace lining for aluminum-melting furnaces. ELISABETH LUX AND HUBERT FRANK (Heinrich Koppers G.m.b.H.). Ger. 660,771, May 12, 1938 (July 14, 1936); VI/31*a*. 2.40. Supplemented by Ger. 664,228, Aug. 4, 1938 (April 13, 1937).—Furnace linings for aluminum-melting furnaces or furnaces having low- or high-frequency a.-c. heating units, where the lining is subjected to comparatively high temperatures, are composed of several layers, at least one of which is fabricated essentially of magnesia-alumina spinel. D.A.B.

High melting point silicate refractories. E. J. LAVINO & CO. Brit. 509,901, Aug. 2, 1939 (Jan. 28, 1937).

Hollow brick as sagger for insertion into furnace or oven. C. BAUCARNAUD. Fr. 847,342, Oct. 28, 1938. D.A.B.

Muffle or crucible furnace. I. HALL. Brit. 511,573, Aug. 30, 1939 (Feb. 18, 1938).

Obtaining alumina from natural or artificial alkali aluminum silicates. R. ENGLERT & F. BECKER CHEMISCHE FABRIK AND "GALINA" FINANZ-A.-G. Ger. 676,192, May 11, 1939 (Jan. 18, 1936); IV*b*/12*m*. 6.—Natural or artificial alkali aluminum silicates are treated with aqueous sulfurous acid. Insoluble matter is removed, and the resulting concentrated solution is heated to a temperature above 70° and below 100°C (80°C being favorable); sulfur dioxide is passed into the solution during and/or after the precipitation of the silicon dioxide. After the precipitation of the SiO_2, the re-solution is worked up to alumina. D.A.B.

Producing a mass suitable for the fabrication of unsintered refractory products. G. E. BOREL AND J. KNABENHAUS. Swiss 203,377, May 23, 1938; *Chem.-Ztg.*, **63** [52] 455 (1939). D.A.B.

Producing refractory products from chrome iron ore (chromite) and overburned crystallized magnesium oxide. E. J. LAVINO & CO. Ger. 676,006, May 4, 1939 (May 20, 1933); VI/80*b*. 8.04.—The chrome ore is subjected to a stabilizing heat treatment at a temperature above 1650° until the physical rearrangement attains equilibrium and the rearranged particles of chromite (possessing a high melting point) are covered with a matrix in the form of a thin film. The amount of over-burned magnesium oxide added to the chrome ore (after the stabilizing heat treatment is discontinued) lies between 12.5 and 25% of the entire weight of the mixture, being measured in a manner corresponding to the amount and composition of the mixture so that no decomposition of the chromite takes place upon future firing or burning of the mass. This mixture is formed and then fired at a temperature above 1650°, temperatures of 1760° and over being most satisfactory. D.A.B.

Production of pure alumina. DYCKERHOFF PORTLAND ZEMENTWERKE A.-G. Brit. 509,892, Aug. 2, 1939 (Jan. 29, 1937).

Refractory. G. E. SEIL (E. J. Lavino & Co.) U. S. 2,170,254, Aug. 22, 1939 (July 1, 1937; Nov. 19, 1937).—A refractory construction unit has a dried but unfired waterproof and cementatory adhering coating which includes a water-insoluble base.

Sintered ceramic mass containing hydrated aluminum silicate. ROSENTHAL-ISOLATOREN G.M.B.H. Ger. 674,674, March 30, 1939 (July 13, 1936); IX/30*b*. 6.04.—The mass contains a minimum of 50% agalmatolite or pyrophyllite and a maximum of 15% clay for reducing shrinkage during firing of the material. D.A.B.

Terra Cotta

Ceramic-glaze technology. G. JUNCK. *Jour. Soc. Chem. Ind. Victoria*, **38**, 131–61 (1938); *Brit. Chem. & Phys. Abs.–B*, **58** [7] 720 (1939).—The materials and principles of glaze formation and the causes and cures of common glaze defects are summarized.

Concept of "unit clay" as an aid to glaze slip control. C. G. HARMAN. *Bull. Amer. Ceram. Soc.*, **18** [9] 332 (1939).

Concrete surfaces faced with glazed tile. G. P. F. BOESE. *Eng. Jour.*, **22** [18] 364 (1939).—B. describes the use of glazed tile for facing concrete, subject to conditions favoring its disintegration. Satisfactory results were secured by utilizing this procedure on concrete in contact with alkaline water. B.C.R.

PATENTS

Apparatus for producing flawless hollow brick having glazed walls and crosspieces by means of the wire press. THOMAS KOIDL. Ger. 675,280, April 13, 1939 (May 6, 1936); VI/80*a*. 28.—The cores arranged within the mouthpiece and the corresponding parts of the mouthpiece have a narrow spacing at places where the clay is supplied to the core; the spacing extends in the direction of the running wire and runs cylindrically in the mouthpiece. D.A.B.

Combination flowerpot. R. H. LOCKYER. U. S. 2,172,514, Sept. 12, 1939 (March 9, 1938).

Corrosion-resistant wall impervious to gas and liquids for absorption, wash, and similar towers. KASPAR KÖNIG (Gewerkschaft Keramchemie-Berggarten Siershahn Westerwald). Ger. 673,895, March 16, 1939 (Oct. 16, 1936); IV*b*/12*e*. 1.02.—The wall brick are composed of corrosion-resistant ceramic material and are laid in a union which enables the taking up of the circular tensile stress that results on the other surface of the brick studs. The brick are arranged over ceramic plates, metal sheets or plates of any acidproof substance, or plates which are not acid-resistant but which have been covered with an acidproof protective layer. These are joined or mortared with acid-resisting materials by soldering, welding, cementing, etc. The space between the brick and the plates is provided with openings which run from the inside to the outside walls; in front of the openings are traps for preventing gases from passing through them. D.A.B.

Device for simultaneously engobing several series of tile in different colors and side by side. JOSEF JACOBI. Ger. 674,437, March 23, 1939 (Feb. 20, 1937); VI/80*a*. 58.—A device is described for the simultaneous engobing in different colors of tile arranged side by side on a revolving conveyer. Double-partitioned hollow separating walls are arranged between the individual rows of brick, which are to be sprayed with different colors while on the conveyer, in such a manner that the walls have slots at the upper and lower parts for the cross props of the conveyer. The walls are so arranged that a backward streaming of compressed air is produced from the upper parts of the separating wall, through the slots for the props of the conveyer, and then to the lower parts of the wall; the air then escapes. D.A.B.

Wedge for use with wall ties. A. M. KINNINGER AND C. A. KINNINGER. U. S. 2,166,444, July 18, 1939 (March 2, 1936).

Whiteware

Adhesion of ceramic masses on metal. GERLACH. *Alba, Beit. zur Kenntnis Edelmetal. als Werkstoffe in Zahnheilkunde*, **1938**, 92–104; *Metals & Alloys*, **10** [8] MA 500 (1939).—Although porcelain seems to have certain advantages over dental alloys in many respects, all-porcelain bridgework is not satisfactory. Research is being concentrated on metal-porcelain combinations. The differences in thermal expansion and gas liberation in the metal during firing introduced difficulties. Pt-Ir alloys are most suitable. G. developed a static testing apparatus in which the adhesion of ceramic masses on dental alloys is tested under shearing stresses. The apparatus is hand-operated, and the breaking load is indicated by a dial guage. Pt and Pt-Ir alloys (20% Ir) in polished and roughened condition were coated with various porcelain mixtures, fired, and tested. The Pt-Ir alloy, superior to Pt in strength, yielded results. The tests with Pd-Ag alloys were not successful. In the majority of tests, the roughened metallic carriers gave the better adhesion values.

Alumina and its use in the china trade. H. J. PLANT. *Trans. Brit. Ceram. Soc.*, **38** [8] 476–90 (1939).—P. discusses the substitution of alumina for flint beds for the elimination of silicosis. R.A.H.

Aristocrat of tableware. ANON. *Ceram. Ind.*, **29** [1] 42–48 (1937).—Lenox, Inc., Trenton, N. J., combines modern methods and skillful hand work to produce the

beautiful ware commonly acknowledged as the world's finest. Production methods are described. Illustrated. E.J.V.

Behavior of suspension-type insulators under mechanical stress. W. FURKERT. *Elektrotech. Z.*, **60** [3] 71–73 (1939).—With the aid of a newly developed testing arrangement, F. found that with the tearing into the porcelain structure a change in the dielectric takes place. This change may be determined with a simple Schering bridge. Capacity and loss factor are measured. If there is no damage to the insulator, there is no change either in capacity or in the loss factor with increasing load. If the load exceeds the strength of the porcelain (this usually produces head cracks), the capacity may increase 1 to 6% while the loss factor changes may be only slight. This new (recording) testing method permits a closer observation of what occurs when suspension-type insulators are subjected to mechanical loads. Diagrams and photos of damaged insulators are shown. L.E.T.

Causes and effects of vitrification in ceramic bodies. R. GUY HARRIS. *Trans. Brit. Ceram. Soc.*, **38** [6] 396–409 (1939).—H. describes the results of experiments made under full-scale works conditions on porcelain bodies produced in large bulk and fired in commercial tunnel kilns. R.A.H.

Delayed crazing. F. T. WOOD AND S. R. HIND. *Trans. Brit. Ceram. Soc.*, **38** [7] 435–54 (1939).—After subjecting various bodies to the autoclave test, the authors found that certain more or less completely vitrified bodies, e.g., an insulator or bone china, instead of expanding as is commonly the case with porous bodies, actually contracted to a limited extent. Harder firing and lower porosity in a body correspond to a reduction in moisture expansion and crazing tendency. Low-fired bodies which, after glazing, were the most porous and had high moisture expansion crazed more readily. R.A.H.

Dielectric loss in ceramics at high frequencies. N. P. BOGORODITSKIĬ AND I. D. FRIDBERG. *Izvest. Akad. Nauk S.S.S.R.*, **1938**, Sér. Phys., 289–97.—An investigation was made to determine the causes for the unusually large dielectric losses observed in Al_2O_3 crystals. The angle of loss was determined at temperatures ranging up to about 600° and under conditions of natural drying. The losses decreased with rising temperature, but even at 100° they were quite large despite the fact that the temperature had been raised slowly. Only at 200° did the losses become small again. Dried specimens which had been moistened showed a large angle of loss. The specific volumetric resistance of such specimens rose at first with increasing temperature but then began to drop. It is concluded that the large dielectric losses in Al_2O_3 of insufficiently compact structure are due to moisture which is contained in certain submicroscopic pores. The dielectric losses of kaolin, quartz, clay, and feldspar components of porcelain were determined. Up to temperatures of 300°C the angle of losses in kaolin was small, but for clays it showed a large increase. The electrical properties of the clays differed, depending upon their alkali content. The feldspar accounted for the large losses of the porcelain. Tests with porcelains having different feldspar contents showed that the angle of loss decreased with decreasing feldspar content. With rising temperature the angle of loss increased with increasing feldspar content. A high-frequency porcelain was prepared by incorporating heavy oxides. This increased the initial angle of loss and also decreased the loss at rising temperatures. Both Isolantite and pyrophyllite had lower electric properties than the high-frequency porcelain. B.Z.K.

Filtration methods in the chemical industry. B. A. MATTHIAS. *Chem.-Ztg.*, **63** [43] 369–71 (1939).—Filters used in the chemical industry are reviewed. 18 references. D.A.B.

Less pinholing in one-fire artware with dip method of casting. ANON. *Ceram. Ind.*, **33** [3] 58, 60 (1939).—At the Purinton Pottery Co., Wellsville, Ohio, a casting method is used in which a group of molds is immersed completely in a vat of the body slip. The molds are placed in two rows, tightly fixed by means of a wooden wedge at one end of each row, and the alloy tray holding the molds is suspended from an overhead monorail. The trays are pushed into position over a tank, and the tank of slip is raised until the molds are entirely submerged. The molds remain immersed for about 15 min. and are then allowed to drain. Molds are coated on the outside with a special type of aluminum paint, and little drying occurs inside the mold; cast ware, therefore, may remain in the mold for as long as 7 or 8 hr. and stay in the leather-hard condition, allowing extreme flexibility in the shop operating scheme. In addition, since the mold is completely immersed in the slip, air pressure on the top surface of the slip pushes the air out of the mold more completely, resulting in a great decrease in pinholing. A considerable labor saving is effected, since two men can operate one rack. Because the slip enters the molds quite evenly, occurrence of stain marks is eliminated. Absolutely uniform thickness of ware can be maintained in quantity production, greatly reducing the losses in drying and firing. An interesting method of casting a teapot and lid all in one piece is described and illustrated. L.M.C.

Porcelain as material for textile machinery parts. W. BEHA. *Sprechsaal*, **71** [12] 152–53 (1938).—Porcelain is finding greater application for parts of machines used in the textile industry in Germany, both because of the necessity for replacing foreign products with domestic and because porcelain, with its hardness, smoothness, and cleanliness, is adapted for changes and improvements introduced in the production of the newly developed fibrous materials and artificial silks where exceptional care and no friction are necessary. Porcelain is used for bobbin and spool parts, in carding machines, looms, printing and dyeing apparatus, chemical apparatus, in textile laboratories, and for tanks, containers, piping, etc. The question of using glass for the same purposes has not yet been settled. See "Stoneware—," *Ceram. Abs.*, **18** [6] 159 (1939). M.V.C.

Pottery of Vernon Kilns. ANON. *Ceram. Ind.*, **29** [3] 183–85 (1937).—In 1931, Vernon Kilns (Vernon, Calif.) was making a very ordinary ware, 90% being sold to chain stores. A complete change in the type of ware was made, and Vernon Kilns today produces only good pottery for which there is no competition. The standards are quality, distinctiveness, and originality, and no previous style, pattern, trend, or tradition is followed. Some of the originally executed wholly American designs produced by Vernon Kilns are described. The equipment and operation of the plant are discussed in detail. Illustrated. E.J.V.

PATENTS

Ceramic insulators. N. V. PHILIPS' GLOEILAMPENFABRIEKEN. Brit. 510,475, Aug. 16, 1939 (April 6, 1937).

Electric insulators. BULLERS, LTD., AND H. C. R. DAGNALL. Brit. 509,606, Aug. 2, 1939 (Jan. 18, 1938).

Nonporous spark-plug insulators. A. H. FESSLER, T. G. MCDOUGAL, AND KARL SCHWARTZWALDER (General Motors Corp.). Ger. 673,366, March 2, 1939 (Nov. 13, 1936); VI/80*b*. 8.03.—Vitrified nonporous spark-plug insulators are made from recrystallized alumina and an oxide or several oxides of elements of the second group of the periodic system. The oxide which is added to the sintered compound is present as an aluminate of Ba, Sr, Ca, Cd, or Zn or as a mixture of several of these elements. D.A.B.

Shielded spark plug. HECTOR RABEZZANA (General Motors Corp.). U. S. 2,171,165, Aug. 29, 1939 (Dec. 27, 1938).

Spark plug. A. A. KASARJIAN (Mosler Ignition Corp.). U. S. 2,169,421, Aug. 15, 1939 (Oct. 23, 1936). MARION THOMEN. U. S. 2,171,014, Aug. 29, 1939 (March 1, 1939). HECTOR RABEZZANA (General Motors Corp.). U. S. 2,171,164, Aug. 29, 1939 (June 6, 1938).

Spark-plug insulators. GENERAL MOTORS CORP. Brit. 509,516, Aug. 2, 1939 (March 31, 1937).

Equipment and Apparatus

Accuracy of sieving tests: I–III. D. MacCalman. *Ind. Chemist*, **13** [154] 464–70; [155] 507–13 (1937); **14** [157] 64–66; [158] 101–106; [159] 143–48; [160] 197–200; [161] 231–36; [163] 306–309; [164] 363–67; [165] 386–90; [167] 498–501 (1938); **15** [171] 161–67; [172] 184–88, 206; [173] 247–51; [174] 290–93 (1939).—Sieve standards are reviewed. The making of test sieves, from the wire drawing to the final assembly, is described and illustrated to give a proper appreciation of the possible sources of error. Conclusions are as follows: (1) A great many discrepancies may exist in the grading results of sieves of the same nominal size even when they are in accordance with the dimensional requirements, etc., of the specification. (2) It is apparently impossible to predict the sieving value of a sieve from a knowledge of its dimensional features or to define the absolute influence on grading results of differences in the size range and in the frequency distribution of the aperture widths of sieves of the same nominal size. (3) It is advisable that the sieves used for important grading tests should be first certified as conforming to the dimensional requirements of the specification and then calibrated against a mutually agreed standard with a sample which is representative of the material in question as to shape, size range, and frequency distribution of the particles. (4) Only sieves in good condition should be used, the calibration should be verified at intervals, and the condition and procedure of the sieving test should be precisely defined and rigidly observed. (5) It is emphasized that the correction values for sieves (obtained by means of calibration) are probably not applicable to grading tests on any other material or even to tests on the same material if the size composition is appreciably different from that on which these values were established. (6) The possible discrepancies in grading results, and therefore the maximum correction values for calibrated sieves, should be the practical minimum so that they are less liable to variation on account of normal differences in the particle-size composition of a given material. (7) Consequently, it is desirable that restricted tolerances with controls on aperture should be applied to sieves intended for use on highly accurate work, although special selection at increased cost would thereby be necessitated. (8) A considerable range of wire diameters may obtain in one sieve or over a series of sieves of the same nominal size, even when the dimensional requirements regarding aperture in the existing specification are complied with. (9) Tolerances on wire diameter are required to make a sieve specification precise and complete, and tolerances on wire size equivalent to those existing in other specifications appear applicable to British Standard fine mesh test sieves. (10) Inaccuracies in aperture widths are attributable to errors in pitch as well as to errors in wire diameter. (11) In the absence of more complete data, an ammended method of measurement involving two tests, for certification purposes, is desirable, and the fields in the masks used for this purpose should be distributed as far as practicable over the entire sieving surface. (12) The specification for the sizing of a product by means of sieves should take into account the possible discrepancies in the grading results from repeated tests. H.E.S.

Calyx core drill. Michael P. Tierney. *Mining Congr. Jour.*, **24** [11] 14–21 (1938).—The drill bit consists of a cutting shoe welded to a core barrel and cuts by means of steel shot. For sinking six ventilation shafts at Anaconda's Mountain Con mine a bit 36 in. in diameter and 6 ft. long was used. The drill speed averages 10 to 12 in. per hr. in hard ground. W.D.F.

Combustion furnace. H. W. Dietert Co. *Foundry Trade Jour.*, **59** [1147] 98 (1938).—A high-temperature tubular furnace for testing purposes is described. The heating element is a durable tubular Globar element with an inside diameter of 2 in. The temperature is controlled manually by a step-voltage transformer or automatically by a pyrometer controller. It is available in lengths of 19¼ in. and 30 in. Illustrated. H.E.S.

Concentrating tables for cleaning glass sand. D. N. Griffin. *Mining Congr. Jour.*, **23** [7] 63–64 (1937).—The use of these tables removes heavy minerals occurring free in the sand; the iron-bearing heavy minerals include iron oxides and ilmenite. Acid bleaching, however, is needed to remove iron stain from the sand. At the Westland Security Co., Tarbutton, Texas, feed to the plant contains 0.116% Fe_2O_3. This passes through a 10-mesh screen, through a bowl classifier and a 20-mesh screen, and then over the concentrating tables and through a rake classifier. The product then contains 0.005% Fe_2O_3. Water must be recirculated because of a shortage. W.D.F.

Constitution and application of thermoelectric instruments. L. B. Lambert. *Eng. & Boiler House Rev.*, **53** [2] 108 (1939).—L. describes briefly the use of these instruments for both the measurement and the automatic control of furnace temperatures. B.C.R.

Developments in clayworking machinery. L. J. Sykes. *Trans. Brit. Ceram. Soc.*, **38** [6] 378–95 (1939); see *Ceram. Abs.*, **18** [4] 106 (1939). R.A.H.

Dust-collecting systems. Anon. *U. S. Dept. Labor, Div. Labor Standards, Bull.*, No. 21 (Part 2), pp. 16–22 (1938); condensed in *Concrete, Cement Mill Ed.*, **47**, 147–49 (1939); see "National—," *Ceram. Abs.*, **17** [6] 238 (1938). W.D.F.

Effective wave length in optical pyrometry. F. Hoffmann and C. Tingwaldt. *Z. Instrumentenk.*, **59** [1] 20–30 (1939).—Monochromatic light as used in pyrometry is actually not quite monochromatic, as color filters and slits used for selecting a definite width of the spectrum always let some other wave lengths pass besides the one at which the pyrometer should work. To create a basis for correct comparison, the conception of "effective wave length" is introduced; it is defined as the wave length at which, for monochromatic light, the intensity is equal to that determined in the spectral range of the measurement. The theory for the calculation of the effective wave length is derived for a pyrometer with a color filter and with spectral disintegration of the light. The derived formulas are applied to practical examples. See "Optical—," *Ceram. Abs.*, **18** [3] 81 (1939). M.H.

Firing shrinkage of ceramic products studied by continuous observation. E. K. Keler. *Ogneupory*, **6** [7] 1298–1306 (1938).—The method of continuous observation of the process of shrinkage or expansion of ceramic products on firing yields trustworthy and exact results which cannot be obtained by ordinary methods. The apparatus devised by K. is briefly discussed. M.V.C.

Grinding raw materials. W. L. Maxson. *Foundry Trade Jour.*, **59** [1150] 163–65 (1938).—Practically, grindability has little effect on the total power cost. Comparing the costs of pulverizing coal of 100 grindability and coal of 45 grindability (an extreme case) showed that maintenance, power, and fixed charges amounted to a little over 3¢ per ton more for the latter coal (figuring power at 0.2¢ per kw.-hr.). Grindability tests are chiefly used in deciding on the proper size of equipment to install in a plant and in determining whether or not an existing installation has sufficient pulverizing capacity to carry the load of a given material. H.E.S.

Handling and conveying materials. Anon. *Concrete, Cement Mill Ed.*, **47**, 190–91 (1939).—For conveying pulverized materials, types of pneumatic pipe line systems are a distinct advance over the older bucket elevators, etc., especially as to maintenance costs. W.D.F.

Improved interferometric procedure with application to expansion measurements. James B. Saunders. *Jour. Research Nat. Bur. Standards*, **23** [1] 179–95 (1939); R.P. 1227. Price 10¢.—S. studied the Fizeau interferometric method, as applied to thermal expansion measurements, to determine the source of serious errors and to find means of reducing them. Two types of errors predominate: (1) error caused by tilting of the spacers under mechanical forces and (2) error caused by variations in air-film thickness at the contact points. Such errors often amount to 10% and may, under certain conditions, exceed in magnitude 50% of the value sought. The two types of errors are considered in detail, and a modified procedure is given

whereby they are reduced to the magnitude of other unavoidable errors, such as those in reading the fringes and in determining the actual temperature of the specimens. R.A.H.

Jewel-inspection microscope. F. E. J. OCKENDEN. *Jour. Sci. Instruments*, **16** [7] 228–30 (1939).—O. describes a microscope incorporating an objective with a built-in illuminator and illuminating system. It is designed particularly for use in measuring the radii of polished spherical surfaces, especially those of the order of 0.1 mm. or less. Illustrated. J.L.G.

Measurements of heat capacity and heat of vaporization of water in the range 0° to 100°C. NATHAN S. OSBORNE, HAROLD F. STIMSON, AND DEFOE C. GINNINGS. *Jour. Research Nat. Bur. Standards*, **23** [2] 197–260 (1939); R.P. 1228. Price 10¢.—Complete new calorimetric equipment was designed and built, and from 256 heat-capacity experiments and 152 vaporization experiments, as finally reduced and formulated, a group of properties of water was obtained comprising specific heat, enthalpy of both liquid and vapor, heat of vaporization, and specific volume of saturated vapor in the range 0° to 100°C. R.A.H.

Miller System machine in pottery manufacture. ANON. *Nat. Glass Budget*, **53** [49] 3, 7 (1938).—A recent installation has operated successfully for a number of months, making both cups and plates at the rate of 984 pieces per hr. H.E.S.

Operation of bowl classifier in conjunction with slurry thickener. ANON. *Concrete, Cement Mill Ed.*, **47**, 174–75 (1939).—The bowl classifier is in closed circuit with a secondary grinding unit. W.D.F.

Parallel scale slide rule developed to calculate vapor-pressure data. F. J. SMITH AND H. B. SHARP. *Oil & Gas Jour.*, **34** [52] 188 (1936).—The construction of the rule is described and illustrated. A single setting of the slide permits reading directly the vapor pressure of hydrocarbons up to normal heptane. F.G.H.

Polarized light. W. E. FORSYTHE AND E. Q. ADAMS. *Gen. Elec. Rev.*, **42** [8] 346–52 (1939).—The nature of polarized light is discussed under the following headings: radiation and polarization as electromagnetic phenomena, physical aspects of polarization, types of polarization and its production, and uses of polarized light. 14 diagrams and two illustrations. L.E.T.

Principles of drying. W. COWEN. *Jour. Soc. Dyers & Colourists*, **55**, 290–302 (1939); *Chem. Abs.*, **33**, 5708 (1939).—The rate of moisture removal is dependent on several factors which can be divided into two groups. One group embraces the physical properties of the material being dried, and the other includes the external factors known as the drying conditions. Drying conditions include the temperature, relative humidity, and velocity of the air, the relative geometrical arrangement of the drying substance and the air stream, and the presence in the drier of heat-radiating and heat-conducting bodies. The particles constituting a moving fluid conform to one of two types of motion, streamline or turbulent. For any standard pressure a psychrometric chart can be constructed to show the absolute humidity, the relative humidity, the humid heat, dew point, and wet- and dry-bulb temperatures and to indicate the changes in the state of an air-water mixture as it becomes more humid in contact with wet material under adiabatic conditions. A psychrometric chart is illustrated. Regain, or equivalent moisture content, drying, constant-rate drying, and the falling-rate period are discussed. In Appendix I the boundary layer theorem is discussed, and Appendix II deals with the rate of drying when the operation is controlled by the movement of the liquid through the solid. A lengthy bibliography is included.

Pulverizability of substances. A. H. M. ANDREASEN, N. HOFMAN-BANG, AND N. H. RASMUSSEN. *Kolloid-Z.*, **86**, 70–77 (1939).—A method and apparatus are described whereby powdered materials are tested for pulverizability, i.e., the ability to form an aero suspension. The more easily the powder is dispersed into dust, the greater is its degree of pulverizability (*Steubungsvermoegen*). A powdered material is passed through a vertical glass tube 45 mm. in inside diameter and 2.5 m. high, and the time required for the material to settle at the bottom of the tube is recorded. Quartz powder, 10 μ fine, requires 0.7 sec. in a vacuum and 200 sec. in air, both values being calculated from Stokes' law, whereby the viscosity of air is given as 0.000189. Calcined flint was ground in a ball mill for 1, 3, 8, and 25 hr., and the powders were tested by this method. The pulverizability number represents the amount (%) of material still floating in the tube after 6 sec. Flint ground for 1 hr. has a pulverizability number of 21; for 3½ hr., 14; for 10 hr., 11; and for 25 hr., 8. This proves that the pulverizability of a substance decreases considerably with increase in fineness. When the finest fractions from a ground material are removed, an increase in the pulverizability takes place. L.E.T.

Relative safe rates of drying of different clay sizes and shapes. H. H. MACEY. *Trans. Brit. Ceram. Soc.*, **38** [8] 464–68 (1939); see *Ceram. Abs.*, **18** [3] 81 (1939). R.A.H.

Safe drying of large fire-clay blocks. H. H. MACEY. *Trans. Brit. Ceram. Soc.*, **38** [8] 469–75 (1939); see *Ceram. Abs.*, **18** [3] 81 (1939). R.A.H.

Selecting and installing industrial thermometers. E. H. HAMMOND. *Power*, **83** [5] 284–85 (1939).—Illustrated. F.G.H.

Selecting leather belts. L. H. SKONGOR. *Power*, **83** [7] 401–403 (1939).—Examples show the use of the new American Leather Belting Assn. standards for selecting flat leather belts. Illustrated. F.G.H.

Sensible sizes for sheaves, pulleys, sprockets, and gears. B. S. WEAVER. *Power*, **82** [2] 72–73 (1938).—W. presents a common-sense guide for choosing the best diameter of the drive element, considering first cost, efficiency, dependability, and low maintenance. Sprockets, gears, flat-belt pulleys, and V-belt sheaves are discussed. Illustrated. F.G.H.

Sensitive pyramidal-diamond tool for indentation measurements. FREDERICK KNOOP, CHAUNCEY G. PETERS, AND WALTER B. EMERSON. *Jour. Research Nat. Bur. Standards*, **23** [1] 39–62 (1939); R.P. 1220. Price 10¢.—A sensitive diamond indenting tool gives indentations of accurately measurable length in the most resistant steels with loads of less than 1 kg. The use of these light loads permits extension of indentation tests to small specimens and to tests of brittle materials, such as glasses, which shatter under the heavy loads required by present indenters. Comparison is made of indentation numbers given by this indenter with corresponding Brinell and Vickers numbers for the same specimens. R.A.H.

Slurry-filter installations return the investment. ANON. *Concrete, Cement Mill Ed.*, **47**, 158–59 (1939).—The filters are of the drum or the disk type. They reduce the water content from 35 to 50% to 18 to 19%. Plants using clays with a high colloidal content may be unable to use these filters. W.D.F.

Structure of porous ceramic materials. B. TAVASCI. *Chimica & Industria*, **21** [6] 329–37 (1939).—The impossibility of studying the physical properties of porous ceramic materials by ordinary microscopic methods is explained; a sufficiently thin section cannot be made for study in transparent light, and reflected light must be applied. The preparation of samples and the method used are described in detail, and structural micrographs of clays in different stages of treatment (green and fired) are reproduced. The application of the method for chemicophysical analysis is explained briefly. M.H.

Symposium on "Improved processing and control methods for ceramic raw materials": I, Controlled mixing. E. M. RUPP. *Bull. Amer. Ceram. Soc.*, **18** [9] 317–18 (1939). **II, Preparation of air-floated clays.** R. C. MEEKER. *Ibid.*, pp. 318–19. **III, Application of dry-mix process in plastic body preparation.** F. A. FIX. *Ibid.*, pp. 319–20. **IV, Plastic mixing.** H. FRAHME. *Ibid.*, pp. 320–21. **V, Fractionation of clays and products resulting therefrom.** S. C. LYONS. *Ibid.*, pp. 321–22.

Theoretical foundations of grinding. ADOLF SMEKAL. *Z. Ver. Deut. Ing., Beiheft Folge*, **1937**, pp. 1–4; *Chem. Abs.*, **31**, 3340 (1937).—When a brittle substance is crushed, the break begins at a point where the tension is of the order

of the maximum molecular shear stress. This stress is proportional to the square root of the modulus of elasticity and the surface energy and inversely proportional to the square root of the molecular range of action. The effect of temperature is connected with release of stress due to self diffusion. Adsorbed chemical substances may lower the work of crushing by decreasing the surface energy. Technical rupture stress is 100 to 1000 times less than the theoretical, owing to crystal defects. These defects may be dense as in rock salt, medium dense as in quartz, or slight as in mica. The separation of defects is usually 0.1 to 1 micron. The ratio of true surface to the geometric surface decreases as the size of grain decreases and approaches unity when the size of grain is equal to the separation of defects. Since grinding proceeds with loss of the most active defects, the specific work must continuously increase with increase in surface. Therefore the laws of Rittinger and of Kick cannot be generally valid. See "Working—," *Ceram. Abs.*, **18** [5] 134 (1939).

Thermal extensometer. I. PELEVOY. *Tech. Phys. U.S.S.R.*, **3** [11] 973–81 (1936); abstracted in *Physik. Ber.*, **18** [9] 797 (1937).—P. describes a new device for determining thermal expansion, in which the sample forms a rod which is clamped on one end. If heated electrically by a coil, the rod closes a contact on the free end when it has expanded a definite length. M.H.

Thermal properties of saturated water and steam. NATHAN S. OSBORNE, HAROLD F. STIMSON, AND DEFOE C. GINNINGS. *Jour. Research Nat. Bur. Standards*, **23** [2] 261–70 (1939); R.P. 1229. Price 5¢.—As a result of new measurements of heat capacity and heat of vaporization of water in the range 0° to 100°C, it is possible to compile into a single table of smoothed values the properties of saturated water and steam. The table is given. R.A.H.

Three-dimensional drawing in mining practice. LEON VALOIS. *Can. Mining Jour.*, **60** [7] 397–403 (1939). G.M.H.

Tool steel. S. C. SPALDING. *Amer. Machinist*, **83** [14] 514–16; [15] 567–68 (1939).—To facilitate the selection of a suitable tool steel for working a given alloy steel, the tool steels are grouped under the following classifications: (1) C steels (also with low Cr and V), used for general purposes; (2) oil-hardening tool steels which are nondeforming steels and contain enough alloy, mostly Mg, to be hardened with an oil quench; C is usually 0.90% and Mn about 1.40%, with small percentages of W, Cr, and V; (3) low alloy steels, special die steels, and chisel steels; the alloy content does not exceed 6%, and they are used for fast finishing or semihigh-speed steels; they have a high C and W content and are water-hardened; (4) high alloy steels and high C and Cr steels, which hold their hardness at red heat. Proper design and shape are important to prevent fracture by overstressing. See "Purchase—," *Ceram. Abs.*, **17** [11] 360 (1938). M.H.

Trends in diamond drilling. HARRY A. KURTZE. *Mining Congr. Jour.*, **25** [8] 47–48 (1939).—The diamond drill is being used to some extent for blast hole drilling. W.D.F.

Wear- and abrasion-resistant surfaces. ANON. *Product Eng.*, **10**, 162–65 (April, 1939); *Metals & Alloys*, **10** [7] MA 450 (1939).—A useful and comprehensive compilation is given of the various types of surface finish, hard-facing, hardening by heat treatment, and of the metals and materials to which the respective surface treatment can be applied to obtain the best possible abrasion and wear resistance.

BOOK AND SEPARATE PUBLICATION

Fan Engineering. Edited by RICHARD D. MADISON. Buffalo Forge Co., Buffalo, N. Y., 1938. 4th ed. 740 pp. Price $4.00. Reviewed in *Power*, **83** [5] 312A (1939).—A new section on fan details, performance of typical fans, and selection of equipment differentiates this volume from earlier editions. F.G.H.

Hydro-Clone Dust Collector. STURTEVANT MILL CO. Reviewed in *Chem. Industries*, **44** [1] 45 (1939).—This collector has no moving parts except an exhaust fan which handles only clean air. Coarse dust is removed dry, while the fine dust is removed in water as a sludge. P.G.H.

PATENTS

Abrasive throwing machine. V. E. MINICH (American Foundry Equipment Co.). U. S. 2,170,831, Aug. 29, 1939 (May 25, 1934; renewed Nov. 25, 1938). U. S. 2,170,832, Aug. 29, 1939 (May 25, 1934; Nov. 11, 1935; renewed April 13, 1939).

Apparatus for producing sized ceramic particles. E. T. HERMANN. U. S. 2,172,638, Sept. 12, 1939 (Oct. 1, 1934).

Attrition mill. G. F. AINSA (Dolores Ainsa). U. S. 2,171,525, Sept. 5, 1939 (Oct. 4, 1933).—In a pulverizing mill, the combination of a centrifugal bowl-like rotor adapted to rotate about a horizontal axis and means for driving the rotor at high speed.

Charging apparatus for charges to be pressed. HEINRICH KÖHLER. Ger. 676,478, May 11, 1939 (Jan. 25, 1938); VI/80*a*. 25.05.—In charging apparatus for presses with circular rollers, with a centrifugal wheel serving for the feeding of the charge, the housing is provided with an outlet opening for air in addition to the openings for the charge. The opening for escaping air is screened off against the projection path of the charge coming from the centrifugal wheel by means of a top covering arranged in such a manner that a narrow slit or opening is formed for the passage of air to its outlet which deviates the current direction of the air in this slot away from the projection path of the charge. D.A.B.

Conveyer. H. V. SCHWEITZER. U. S. 2,169,772, Aug. 15, 1939 (Nov. 11, 1935; July 3, 1936).—The combination of a traveling conveyer of yieldable, flexible material, supporting means for the conveyer comprising spherical elements spaced transversely and longitudinally thereof, and slender elements carried by the conveyer, the elements extending from the conveyer and providing supporting points spaced apart and from the conveyer for supporting articles of ceramic materials so that substantially the entire surfaces of articles resting on the points are substantially unobstructed by the conveyer and by the elements and are accessible for treatment while the conveyer is in motion.

Machine for preparing clay, etc. FELIX KERN. Ger. 674,902, April 6, 1939 (Jan. 8, 1937); VI/80*a*. 1.05.—The charge of clay, etc., is pressed through the openings in the wall of the apparatus by means of a striking tool. The apparatus is provided with one or more troughs or vats located lengthwise in series, having a semicircular or segmented-like cross section at the base and being provided with holes, grates, or sieves, and a stirring, striking, and cutting tool arranged along the shaft running lengthwise within the machine. D.A.B.

Manufacture of ceramic tubing. J. D. MORGAN AND R. E. LOWE (Power Patents Co.). U. S. 2,171,006, Aug. 29, 1939 (July 18, 1936).

Metallic abrasive. J. F. ERVIN. U. S. 2,171,081, Aug. 29, 1939 (May 10, 1937; Dec. 19, 1938).—An abrasive material characterized by a high crushing strength and impact resistance comprises a high carbon ferrous base alloy containing substantially 3 carbon, 0.5 manganese, 1.5 silicon, 0.1 sulfur, 0.4 phosphorus, 0.25 to 3.0 chromium, and 0.1 to 0.6% molybdenum, the remainder of the composition being iron.

Metallic abrasive. J. F. ERVIN. U. S. 2,171,082, Aug. 29, 1939 (May 10, 1937; Dec. 19, 1938).—An abrasive material characterized by a high impact resistance and crushing strength comprises a high carbon ferrous base alloy containing substantially 3 carbon, 0.5 manganese, 1.5 silicon, 0.1 sulfur, 0.4 phosphorus, 0.1 to 1.5 chromium, 0.1 to 3 nickel, and 0.1 to 0.6% molybdenum, the remainder being iron.

Metallic abrasive. J. F. ERVIN. U. S. 2,171,083, Aug. 29, 1939 (May 10, 1937; Dec. 19, 1938).—An abrasive material characterized by a high impact resistance and crushing strength comprises a high carbon ferrous base alloy containing substantially 3 carbon, 0.5 manganese, 1.5 silicon, 0.1 sulfur, 0.4 phosphorus, 0.1 to 1.5 chromium, 0.1 to 3 nickel, and effective amounts and up to 0.06% vanadium, the remainder being essentially iron.

Method and furnace for sintering cement, lime, magnesite, etc. H. EBERLE. Swiss 203,903, Sept. 19, 1938; *Chem.-Ztg.*, **63** [59–60] 511 (1939). D.A.B.

Reduction mill. G. F. AINSA (D. C. Ainsa). U. S. 2,171,526, Sept. 5, 1939 (April 1, 1935).—In a centrifugal reducing mill, the combination of an open ended bowl-like element adapted to rotate at high speed and centrifugally throw material to be reduced, hopper means for directing agglomerate to be reduced into the open ended bowl-like element while the element is in rotation, an impact-receiving member disposed about the open end of the rotor element, a rotatable drumlike housing adjacent the open end of the impact-receiving member and encircling the hopper for catching the agglomerate discharged from the impact-receiving member, the housing having a plurality of buckets disposed about its inner peripheral surface, an annular baffle forming partition adjacent one end of the drumlike housing, means providing a circulation of water through the lower part of the drumlike housing coöperating with the annular baffle to separate the reduced from the unreduced agglomerate and discharging it at the end of the housing, and means for rotating the drumlike housing whereby the buckets disposed therein will return the unreduced agglomerate to the hopper means.

Revolving tubular or swing furnace for sintering clay, etc. EMRIK IVAR LINDMAN. Ger. 676,479, May 11, 1939 (Dec. 11, 1935); V/80*c*. 14.01.—A revolving tubular or swing furnace sinters clay or similar masses or a mixture of these masses until a transmittant refractory state is obtained, with expansion of the material by gases liberated in the raw material or gases produced upon sintering of a part of the material, and a cell-like clinker-like product is produced. The furnace wall has a lining which, in comparison with the charge, has a good thermal conductivity and is cooled from without, so that a heating is provided which heats less intensely that part of the mass which is in consideration in the case of the rolling motion of the furnace causing the material to come in contact with the furnace wall than the other parts of the mass, and an inlet is arranged through which a current of cooling air or gas enters which flows through the furnace beside the flame of the burner, i.e., through the chamber which is bound by the furnace wall, the lesser-heated part of the mass, and the flame. The degree of cooling of the current of air or gas and of the furnace wall is determined in such a manner that a thin crust forms on the mass directly in contact with the furnace wall; this crust is sufficiently strong to prevent an adhesion with the furnace wall. D.A.B.

Rolling or milling molded articles, e.g., brick and tile. LUDWIG LUDOWICI. Ger. 671,441, Jan. 19, 1939 (July 11, 1933); VI/80*a*. 23.01.—Molded articles, e.g., brick and tile, are rolled or milled by employing a clay cutter having hollow spaces and forming the mass stronger than the finished brick. The hollow spaces are pressed against the place on the brick where the grooves are to be produced, entirely or partially during the processing of the brick. D.A.B.

Rotary labeling machines for bottles, flasks, cans, etc. BRASS-CAV. Brit. 509,822, Aug. 2, 1939 (Nov. 21, 1936).

Spray apparatus. G. H. BUZZARD AND H. A. ROSELUND (DeVilbiss Co.). U. S. 2,169,514, Aug. 15, 1939 (Sept. 1, 1937).

Tile-cutting machine. N. C. COATES. U. S. 2,171,024, Aug. 29, 1939 (Jan. 19, 1938).

Kilns, Furnaces, Fuels, and Combustion

Advancements in kiln construction offer more efficient firing. T. W. GARVE. *Brick & Clay Record*, **94** [4] 26, 43–44 (1939).—The use of insulating refractory brick, not only for the construction of arches and crowns but also for entire kiln walls, results in a reduction in weight of the brick and a saving in brick and brick construction, space, and heat units. In kiln construction, expansion in every part of the kiln must be provided for. Care must be taken in constructing kiln walls to prevent bulging under the expanding pressure of the kiln floor. The design and construction of kiln bottoms are discussed. Heat losses can be minimized by (1) better constructed and insulated crowns, (2) the use of the flat suspended crown wherever possible, (3) thinner walls and ample use of refractory insulating brick, (4) kiln expansion joints to prevent leakage, (5) insulation of the bottom of the kiln, (6) proper kiln and furnace design, (7) protecting kilns from the weather, and (8) proper firing methods.

Application of electric heat in enameling faience tile. PIERRE GRISEL. *Rev. Chauffage Elec.*, **6** [6–7] 143–46 (1938).—G. gives a brief description of intermittent furnaces (muffle and bell furnaces) and continuous furnaces (the multiple-passage furnace and tunnel kiln). A comparison diagram shows the great economy of heat obtained in electric furnaces as compared with furnaces heated with other fuels. M.V.C.

Application of the tube method for measuring the normal speed of flame propagation in gases. L. KHITRIN. *Tech. Phys. U.S.S.R.*, **4** [2] 110–20 (1937); abstracted in *Fuel*, **17** [1] 30 (1938).—A critical historical review of examples of the use being made of the tube method for studying the slower processes of flame propagation is followed by a description of experiments aiming at supplementing and extending the results obtained by Coward and Hartwell (*Jour. Chem. Soc.* [London], **1932**, p. 1996, p. 2076) in investigating the connection between the dimensions and shape of the flame surface and velocity of its displacement along the tube. Another object of the experiments was to compare the results with those found by the burner method and by Stevens' "constant pressure bomb" method. The procedure in recording the observed phenomena was similar to that followed by Coward and Hartwell. When carried out and analyzed correctly, the three methods lead to identical results. K. reached the following conclusions: (1) The speed of uniform flame movement is not in itself a value characteristic of the normal speed of propagation which it is desired to find; it is a value proportional to the general quantity of the mixture ignited in unit time and depends on the dimensions of the flame surface and on the conditions of propagation. (2) The value of the normal speed of inflammation should always be determined as the ratio of the volume of fuel mixture consumed in unit time to the area of the surface of inflammation. This is a result of "Gouy's postulate" and a consequence of the nature of normal combustion. In view of this, there is no necessity for the new term "fundamental speed" proposed by Coward and Hartwell for the relation between the gas ignited in unit time and the area of the surface. (3) The tube method permits a sufficiently accurate determination of the value of the normal speed, but to achieve this it is necessary to record the shape and dimensions of the flame surface that correspond to the stage of uniform movement. (4) The value of the speed of movement may, in general, serve as a relative characteristic of the process of propagation in cases where the external physical conditions remain unchanged. In any other case, possible changes in the dimensions of the flame surface may lead to incorrect results. It is always necessary to bear this circumstance in mind.

Calculating the number of brick for kiln arches and crowns. T. W. GARVE. *Brick & Clay Record*, **95** [1] 15–21 (1939).—Arches and kiln crowns, which are constantly exposed to high heat, fail before the walls or other parts of the structure require repairing; therefore special attention must be given to them. Intelligent use of the proper sizes and shapes increases the life of arches and crowns. Special large units with interlocking or overlapping features are often used to advantage by refractory concerns who make their own shapes. Certain small units, however, are needed for expansion joints, and too large blocks are apt to crack. Formulas provide accurate determinations for each number of units. Drawings showing the actual methods of computing crowns and arches are given, including a table for the selection of arch brick and straights.

Electric 24-passage kiln for firing enamel on faience tile. M. R. LEBEGUE. *Rev. Chauffage Elec.*, **7** [5] 98–100 (1939).—The multiple-passage kiln, although it eliminates the use of saggers, has heretofore been hard to heat uniformly in all passages; the innovation of electric heating, however, has overcome this disadvantage which especially affects the colors and mechanical properties of enamels. Rows of unfired tile traveling toward the firing zone alternate with rows of returning fired tile. The production capacity is 10,000 to 12,000 tile (15 x 15 weighing 320 g.) per 24 hr. The kiln is described. Among the advantages cited are uniform temperature and constant atmosphere in all passages and reduced personnel. M.V.C.

Electrical model for heat-flow phenomena and its practical utilization for measurements. W. FISCHER. *Elektrowärme*, **9** [7] 133–42 (1939).—Formulas for heat flow are so transformed that they are analogous to those of electric flow. Electrical circuits can be set up, based on these transformed equations, which correspond to heat flow and are susceptible for numerical evaluation. Examples of heating up a furnace, of the distribution of heat supplied between furnace and heated goods, and for stationary and dynamic heating conditions illustrate the application of the method. M.H.

Estimation of oil and gas reserves. R. L. HUNTINGTON. *Oil & Gas Jour.*, **35** [22] 124–27 (1936). F.G.H.

Kinetics of the decomposition of *n*-butane: I, Normal decomposition. LEONARD S. ECHOLS AND ROBERT N. PEASE. *Jour. Amer. Chem. Soc.*, **61** [1] 208–12 (1939).—A reinvestigation of the kinetics of decomposition of *n*-butane has shown that the reaction is far from being the simple unimolecular reaction originally postulated on the basis of flow experiments at 1 atm. The variation of fractional reaction times with initial pressure indicates more nearly an order of 1.3. This can have no primary significance, however, since the rapid initial decrease in rate at any one pressure would require an order of as high as 5 or 6. Data are fitted by the semiempirical equation

$$-\frac{d(p_{C_4H_{10}})}{dt} = k_1 p_{C_4H_{10}}^{1.5} + k_2 \frac{p_{C_4H_{10}}^2}{p_{0C_4H_{10}} - p_{C_4H_{10}}}.$$

The second term indicates inhibition by products and drops out after about 10% reaction. This leaves the first term, corresponding to an order of 1.5, predominating over the remainder of the reaction. F.G.H.

Luminous flame and its application. JAMES E. DARE. *Ceram. Ind.*, **32** [5] 44–48 (1939); *Ind. Gas*, **17** [5] 12–17 (1939).—Luminous flame is obtained by admitting very little or no primary air to a gas burner. The air and gas streams must be parallel and moving at the same speed. Luminous flames are often a more effective source of heat than nonluminous flames, owing to the greater radiation produced. They also have other advantages. Luminous-flame combustion is widely used in the steel industry, the glass industry (for melting, lehrs, mold heating, etc.), for galvanizing and lead melting, in frit furnaces, and in terra-cotta and pottery kilns. Standard luminous flame burners are available in a variety of sizes and types. The application of special burners to glass tanks and open-hearth furnaces is described. S. S.

Nomenclature of the megascopic description of Illinois coals. GILBERT H. CADY. *Econ. Geol.*, **34** [5] 475–94 (1939).—The British names, vitrain, clarain, and durain, and the more commonly used term, fusain, have been adopted by the Illinois Geological Survey as an aid in the megascopic description of the material of the coal beds of the Illinois coal basin. The application of the names is illustrated by 11 photographs. J.L.G.

Silicon carbide resistor furnace. A. MINGARD. *Compt. Rend. 18me Congr. Chim. Ind.*, **1938**, 848–52; *Chem. Abs.*, **33**, 6165 (1939).—A new type of electric resistance furnace is suitable for either laboratory or commercial use. It consists of a SiC resistor rod mounted between two water-cooled metal contacts connected to the current supply. The rod is placed between the walls of two concentric cylinders made of highly refractory material. The outer cylinder is embedded in Kestner cement and acts as a thermal insulator, while the inner cylinder is the furnace laboratory. The advantages of this furnace over C-resistance furnaces are absence of evolution of CO and long life of the resistor.

SEPARATE PUBLICATION

How to Buy, Sell, and Burn Coal. THOMAS A. MARSH. Price $1.00. Reviewed in *Foundry*, **67** [6] 102 (1939). F.G.H.

PATENTS

Apparatus for producing gases which act as reducing agents in tunnel furnaces used for firing porcelain, etc. KERAMISCHE INDUSTRIE BEDARFS KOM.-GES. PAUL GATZKE. Ger. 675,281, April 13, 1939 (Oct. 4, 1935); V/80*c*. 5. Addition to Ger. 649,863.—Gases which are to act as reducing agents are produced in an indirectly heated tunnel furnace, according to Ger. 649,863, from volatilizable combustible liquids with which the chamotte material (being the constituent material from which the plate forms of the carrier for the charge are constructed) is saturated along the front side; the influence of the gradually increasing temperature during the furnace period produces the reducing gases. D.A.B.

Rod- or bar-shaped electrical heating element for producing high temperatures in electric furnaces. SIEMENS & HALSKE A.-G. Ger. 676,728, May 17, 1939 (April 2, 1936); VIII*c*/21*h*. 2.02.—A rod- or bar-shaped electrical heating element for producing high temperatures in electric furnaces has a heat conductor which is surrounded by a tube-shaped ceramic jacket or casing. A heat conductor having a high melting point (tungsten or molybdenum) is arranged in a gastight sintered tube, consisting of ceramic material containing silicates of aluminum and/or magnesium, which is closed or sealed on the ends by metal caps joined with the ceramic tube by means of soldering to render the tube vacuum-tight; the heat conductor is fixed within the spacing (gas-filled or evacuated) which is thermally indifferent in contrast to the heat conductor. D.A.B.

Geology

Aluminum silicates. V. CHARRIN. *Argile*, No. 196, pp. 1–5 (1939).—Sillimanite, allophane, and lepidolite are aluminum silicates with possibilities for the ceramic industry, but their use has been limited because of their scarcity. Sillimanite brick have a high mechanical resistance and withstand temperatures of 1800°. Allophane has a high aluminum content and possesses the curious property of precipitating albuminoids. Lepidolite can be classed in the family of micas and has long been used in the preparation of opal glass and glasses subjected to sudden temperature change. In porcelain manufacture the substitution of lepidolite for feldspar whitens and beautifies the product and increases resistance to thermal shock. Deposits of these minerals in France are cited. See *Ceram. Abs.*, **18** [2] 57 (1939). M.V.C.

Bauxite deposits of the regions of Sohodol (Jud. Alba) and Vidra (Jud. Turda), Rumania. O. PROTESCU. *Inst. geol. Romăniei, Studii tech. econ.*, **1938**, Series A, No. 1, 23 pp.; *Chem. Abs.*, **33**, 512 (1939).—A geological survey of the bauxite deposits of the two regions is followed by a description of the deposits, the physical and chemical properties of the ore, a petrographic and mineralogical characterization, and a brief outline of the industrial organizations in charge of the mining. 32 references.

California's commercial minerals. WALTER W. BRADLEY. *Mining Congr. Jour.*, **24** [9] 16–20 (1938).—California produces important amounts of barite, bentonite and fuller's earth, pottery clay, diatomite, dolomite, gypsum, limestone, pumice and tuff, soapstone, talc, and silica. Smaller amounts of asbestos, feldspar, fluorite,

mica, andalusite-sillimanite-kyanite group, etc., are also produced. W.D.F.

Cation exchange in clay minerals. ULRICH HOFMANN AND KURT GIESE. *Kolloid-Z.*, **87**, 21–36 (1939).—Investigations were made on three clays, one Zettlitz kaolin, and a Ca bentonite, with ammonium chloride. The total amount of exchangeable cations was determined, and the so-called salt-free water skin was determined and considered. Vageler's equation for the determination of the total amount of base-forming cations (*S* value) does not give quite correct results. A similar exchange equation (adapted from Jenney's equation) gave better results. The authors show that it is possible to obtain *S* values with a single determination and to make a second determination with solutions of NH_4Cl to yield values correct to 5%. The size of the salt-free water skin increases with the *S* value in the clays investigated. 32 references. L.E.T.

Drying kaolin and chalk in revolving cylindrical driers. I. S. CHERNYSHEV. *Mineral. Syr'e*, **1938**, No. 1, pp. 51–58; *Khim. Referat. Zhur.*, **1** [4–5] 114 (1938); *Chem. Abs.*, **33**, 6091 (1939).—The investigations performed disproved the belief that as a result of drying at high temperatures kaolin changes its properties because of the loss of its water of constitution, and chalk, because of the evolution of CO_2. New data were found for planning gas revolving cylindrical driers for kaolin and for chalk. A 600° temperature of the flue gases does not affect the physical properties of kaolin in any way. Depending on the experimental régime (initial temperature of the flue gases, 593° and 510°), the following data were obtained: final temperature of the flue gases, 123° and 125°; initial moisture content of kaolin, 20.44 and 19.9%; final moisture content of kaolin, 0.63 and 1.8%; capacity of the drier, 4276 and 3582 kg./hr.; amount of coal used, 215 and 157 kg./hr. No similar data for chalk are given.

Industrial minerals. OLIVER BOWLES. *Mining Congr. Jour.*, **24** [2] 57–59 (1938).—O. reviews progress made in 1937 in methods of treatment and new uses for products. The use of flotation and agglomeration and tabling has increased; dry methods of separation are rapidly progressing. The importance of particle size has been realized. By processing clay, special types now imported can be obtained. Phosphorus is produced from phosphate rock. A new hydraulic gypsum cement is being made. W.D.F.

Maximum exchange capacity and exchange intensity of the hydrated aluminosilicates. N. CERNESCU. *Inst. geol. Romăniei, Studii tech. econ.*, **1938**, Series C, No. 4, 22 pp. (in French); *Chem. Abs.*, **33**, 451 (1939).—In the exchange of the cations in hydrated aluminosilicates, not only the exchange capacity but also the intensity must be considered. The maximum exchange capacity increases with silica in the aluminosilicate, while the exchange intensity decreases.

Methodology of grain-size and mineral analyses of pelites (on the basis of research on elutriation analysis and roentgenographical and microscopical studies of different deposits). HANS-J. HARKORT. *Sprechsaal*, **72** [19] 233–38; [20] 249–54; [21] 265–69; [22] 281–83; [23] 295–98; [24] 310–15; [25] 321–28; [26] 338–41 (1939).—The practicability and limitations of roentgenographic, microscopic, and elutriation analysis methods in the study of pelitic sediments which include clays and soils were investigated: *Grain-size analysis*: (1*a*) particle size in its dependence on the method of determination, (*b*) choice of method of determining the particle size, (*c*) making the sedimentation analysis; (2*a*) double purpose of the grain-size analysis, the requirements for preparation, and practicability, (*b*) characterizing the states of "maximal" and "natural" dispersion, (*c*) fundamentals of the realization of maximal and natural dispersion; (3) preparation and maximal dispersion: (*a*) division as a colloid chemical problem, (*b*) effective colloidal chemical preparation, (*c*) electrolytic addition, (*d*) physically effective preparation, (*e*) chemically effective preparation. *Mineral analysis:* (1) introduction; (2*a*) clay minerals; the mineral constituents are divided into three groups on the basis of their Roentgen diagrams and their chemical composition (kaolin type, "Serezite" type, and montmorillonite-nontronite type) and are characterized microscopically and roentgenographically, (*b*) iron oxide minerals; (3) determination of minerals in heterogeneous mix: (*a*) possibility and difficulties of detection microscopically and roentgenographically of substances in mixes, (*b*) clay mineral mixes, (*c*) iron oxide minerals and kaolin mixes, and (*d*) mixes with nonclay mineral constituents (quartz and clay minerals). M.V.C.

Newfoundland fluorspar. C. K. HOWSE AND R. P. FISCHER. *Eng. Mining Jour.*, **140** [7] 42–45 (1939).—The geology and commercial development of the fluorspar deposits in the St. Lawrence region of Newfoundland are described. Production begun in 1932 has increased steadily to about 10,000 tons shipped in 1938. J.L.G.

Physical properties of clay. E. G. RICHARDSON. *Trans. Brit. Ceram. Soc.*, **38** [6] 359–77 (1939).—R. describes a method for determining (*a*) particle size of clay (glass tank and photoelectric cell) and (*b*) the behavior of clay paste under shearing stress. R.A.H.

Plasticity of clays. LOUIS LONGCHAMBON. *Compt. Rend. 18me Congr. Chim. Ind.*, **1938**, 784–87; *Chem. Abs.*, **33**, 6118 (1939).—Plasticity is a complex property that involves at least two concepts, deformability and cohesion. In relation to the fineness of the grains of hydrated silicoaluminate and to phenomena of adsorption of positive and negative ions, plasticity seems to be the result of an oriented hydration of the micelle which increases the weight of the latter until Brownian movement ceases. The oriented layers of water on the different micelles ensure both cohesion and lubrication of the mass, whence its plasticity. See "Colloidal—," *Ceram. Abs.*, **18** [7] 194 (1939).

Sorting. M. W. VON BERNEWITZ. *Mining Congr. Jour.*, **23** [12] 14–17 (1937).—B. reviews sorting practice and mentions its applications to asbestos, barite, china clay, feldspar, fluorite, Iceland spar, limestone, magnesite, sillimanite, stone, metallic minerals, and coal. W.D.F.

Ural dunites. A. D. FEDOSEEV AND F. A. ZENKOVICH. *Ogneupory*, **6** [8] 1395–99 (1938).—A short description of the chief deposits of dunite located in the Urals is given. Laboratory experiments show that these dunites are excellent raw material for the production of forsterite refractories. M.V.C.

BOOKS AND SEPARATE PUBLICATIONS

Bentonite in Wyoming. J. H. HEATHMAN. *Geol. Survey Wyoming Bull.*, No. 28, 20 pp. (1939).—H. discusses stratigraphic occurrence and distribution and gives a brief summary of the history, production methods, and the more important uses. Bentonite is defined as a clay material which contains 75% or more of montmorillonite or beidellite. Analysis of an average bentonite is as follows: SiO_2 61.94, Al_2O_3 15.97, P_2O_5 0.07, Fe_2O_3 2.92, FeO 0.71, MgO 2.45, CaO 1.72, Na_2O 1.61, K_2O 0.29, H_2O- 7.17, H_2O+ 3.95, TiO_2 0.23, CO_2 0.41, SO_3 0.15, S 0.01, and C 0.14%. The best bentonites in Wyo. are found in the lower part of the Upper Cretaceous series. The bentonite in these formations differs in character in different parts of the state, but whether or not this influences the swelling property of the bentonite has not yet been established. Bentonite seams, as a rule, thicken and thin from place to place. An exception is a thick seam at the top of the Mowry which is present throughout more than half of the area of the state. At present, the Black Hills and Bighorn Basin areas are, and will probably be for many years, the principal producing areas in Wyo. because of low mining costs and the proximity to railroads. A.G.S.

Future of Canadian mining. T. A. CRERAR. Canadian Department of Mines, Ottawa, 1936. 83 pp., 11 figs. Price 25¢.—Twelve radio addresses delivered over the Canadian Radio Commission network during 1936 are presented. G.M.H.

Magnesium, Magnesite, and Dolomite. J. LUMSDEN. Imperial Institute, London, 1939. 126 pp. Price 2s 6d net, postage 4d. Reviewed in *Can. Mining Jour.*, **60** [7] 434 (1939).—India has extensive magnesite deposits. The

mineral is worked to a lesser extent in South Africa and Australia. Canada has large reserves of magnesitic dolomite. L. discusses British and foreign deposits of magnesite and dolomite and describes magnesium metal and magnesite as a refractory material. G.M.H.

Occurrence of Bauxite in British Guiana. Compiled by D. W. BISHOPP. *Bull. Geol. Survey Brit. Guiana*, No. 8, 67 pp. (1938). Govt. Printers, Georgetown, Dumerara. Reviewed in *Bull. Imperial Inst.*, **36** [4] 513–14 (1938).—The historical development of the bauxite deposits is described briefly, and considerable space is given to a description of the various deposits which have been examined. A theoretical discussion of the geology and origin of bauxite is included. See "British Guiana—," *Ceram. Abs.*, **16** [2] 73 (1937). A.P.S.

PATENT

Recovering residual glass sand. N. S. GARBISCH. Fr. 847,636, Dec. 16, 1938. D.A.B.

Chemistry and Physics

Determination of aluminum by 8-hydroxyquinoline. G. STANLEY SMITH. *Analyst*, **64** [761] 577–81 (1939).—The use of 8-hydroxyquinoline is suitable for separating aluminum present in concentrations up to 0.01 g. per 100 ml. of solution. The procedure is also useful for separating small amounts of aluminum from large amounts of magnesium. B.C.R.

Electrical conductivity and dielectric constant of quartz and other crystals. R. NASSER-GHOLI. *Jour. Phys. & Radium*, **9** [7] 291–96 (1938).—Prolonged heating at about 700° greatly diminishes the conductivity of crystals of quartz in comparison with the conductivity of the cold crystal. The diminution is still greater if the crystal is kept under tension during the heating period. The electric capacity varies linearly with the temperature according to the equation $C=At+B$. Any deviations from the equation disappear after annealing. J.S.

Iron, manganese, and other heavy metals in waters. O. PERLO. *Argile*, No. 196, pp. 5–9 (1939).—The importance of the presence of heavy metals, such as iron, manganese, lead, copper, etc., or their salts in waters used in the ceramic industry is enormous, and the amount present should be determined periodically. Rapid and simple tests for their determination are given. M.V.C.

Laue patterns by reflected X rays. D. E. THOMAS. *Jour. Sci. Instruments*, **16** [7] 222–28 (1939).—T. describes a method of obtaining Laue patterns from single crystals in sections of metal ingots and explains the experimental technique used in determining the orientation of the crystals. 9 figures. J.L.G.

Necessity of two definitions of surface tension. L. BRILLOUIN. *Jour. Phys. & Radium*, **9** [11] 462–64 (1938).—An examination of the literature shows that there are two definitions of surface tension. The definitions are usually used interchangeably without any distinction. If A is the free energy of a gram molecule stretched over a surface (B) in a surface layer, the surface tension (C) is $\frac{A}{B}$ or $\frac{\partial A}{\partial B}$, depending upon the definition used. J.S.

Piezoelectric constant of quartz. J. CLAY AND J. G. KARPER. *Physica*, **4** [4] 311–15 (1937); abstracted in *Physik. Ber.*, **18** [15] 1402–1403 (1937).—The dielectric coefficient was measured up to 10 kg./cm.^{2}; up to 90°C a small temperature coefficient was found. M.H.

Surface tension in different states of aggregation. G. ANTONOW. *Ann. Physik*, **35**, 84–96 (1939).—Surface tension can usually be determined only for the liquid state; that of solid substances requires different methods. A new method was developed on the following principle: If two media are in contact and in equilibrium, the relation (Antonow's rule) $\alpha_{AB}=\alpha_A-\alpha_B$ exists, where α_{AB} = the tension of the boundary areas, α_A = the surface tension of the medium A, and α_B = that of the medium B. The latter is now arranged in such a manner that $\alpha_{AB}=0$; in this case the two surface tensions of A and B become equal, and if one is a solid (glass or metal) and the other a liquid, the surface tension of the solid can be determined. The procedure for the experiments is described in detail; the surface tension of glass was found to be 130 dynes/cm. (varying slightly with the type of glass), and that of rock salt, 300 dynes/cm. No direct determination could be made for metals; indirect proofs point to values of 1000 dynes/cm. and more. 25 references. M.H.

System PbO–B_2O_3–SiO_2. R. F. GELLER AND E. N. BUNTING. *Jour. Research Nat. Bur. Standards*, **23** [2] 275–83 (1939); R.P. 1231. Price 5¢.—The compositions studied have some potential value for those interested in stable low-melting glasses of high refractive index. Their value as ceramic glazes is limited. Phase relations within the system resemble those for the system CaO–B_2O_3–SiO_2 in two particulars: (1) the two-liquid area covers a large portion of the diagram and (2) the one ternary compound possessing a field in each system has the same molecular ratio (5:1:1). The new compound, $5PbO\cdot B_2O_3\cdot SiO_2$, melts incongruently at 551°C to form $2PbOSiO_2$ and liquid. It is negative in character, and the X-ray pattern shows orthorhombic, and therefore biaxial, structure. Interference figures indicate that the crystals are nearly, or quite, uniaxial. The indices of refraction are 2.04 and 2.085. The liquidus of the lowest-melting eutectic is at 484°C and 84.5 PbO, 11.0 B_2O_3, and 4.5% SiO_2. R.A.H.

Viscosity and particle size. E. A. HAUSER AND D. S. LE BEAU. *Kolloid-Z.*, **86**, 105–107 (1939).—A 1.5% bentonite suspension was freed from coarser particles first by sedimentation and then by treatment in a high-speed centrifuge, resulting in a diluted bentonite sol with a particle size ranging from 10 to 200 mμ. The absolute viscosity was then determined on the Höppler viscosimeter. The viscosity decreases with increased particle size up to a constant value. At 25°C the viscosity of particles of 10 mμ is 14.1; of particles of 23 mμ diameter, 4.7; and of particles of 48 to 200 mμ diameter, 2.0 cp.; the viscosity of the last particles remains constant. The extreme rise in viscosity of fractions with particles of the smallest diameter, as well as the still comparatively high viscosity compared with the pure dispersion medium (0.893 cp. at 25°C), is explained by the high hydration capacity of the dispersed material. L.E.T.

X-ray diffraction by a crystalline powder on a plane stationary surface. F. DUPRÉ LA TOUR. *Compt. Rend.*, **209** [1] 51–53 (1939).—D. describes a method of determining the constitution of powders by a thin layer of the powder on a plane surface. The theory and formulas are established to permit evaluating the X-ray diagrams which appear in very fine lines and give exact results. A diagram can be taken in 10 min. M.H.

BOOK

Standard Chemical and Technical Dictionary. H. BENNETT. Chemical Publishing Co., Inc., New York, 1939. 638 pp. Price $10.—Over 25,000 definitions are given in this condensed technical word book for students, writers, technicians, engineers, scientists, and all others who need assistance in keeping up with the many new chemical, physical, mathematical, engineering, and technical words. The book is a compilation completely covering industrial products, pure chemicals and trade names, abbreviations, and contractions, as well as the symbols used in mathematics, chemistry, thermodynamics, pharmacy, etc. A special section is devoted to the explanation and the proper naming of the organic compounds. The rules for the nomenclature of the organic compounds are stated clearly. The prefix names of the organic radicals supplement this. Every device has been used to make the dictionary practical and easy to use. Complete cross references are given. Matter of a similar nature is grouped together. A standard system of alphabetizing has been used which makes it

possible to find even the most complex organic compound. The symbols have been arranged so that they can be found at a moment's notice. There is no field of recent endeavor which is not included.

PATENTS

Alkali perborates. DEUTSCHE GOLD- UND SILBER-SCHEIDEANSTALT VORM. ROESSLER. Ger. 675,615, April 27, 1939 (May 24, 1933); IV*b*/12*i*. 16.—Boric acid is transformed by treatment with hydrogen peroxide and alkali or hydrogen peroxide and alkali peroxide, or an alkali compound containing boric acid residues is transformed by treatment with hydrogen peroxide and alkali. The entire quantity of compounded water or uncombined water present during the transformation does not exceed the amount of water necessary for complete hydration of the formed perborate by more than 8%; thus a product of dry character can be directly obtained. D.A.B.

Manufacture of beryllium oxide. SERI HOLDING SOC. ANON. Brit. 511,157, Aug. 23, 1939 (Feb. 12, 1937).

Producing products containing amorphous silicic acid M. HAUSER. Swiss 203,376, Sept. 29, 1937; *Chem.-Ztg.*, **63** [52] 455 (1939). D.A.B.

Production of highly voluminous silicon dioxide. ALKALIWERKE WESTEREGELN G.M.B.H. Ger. 675,815, April 27, 1939 (Dec. 18, 1935); IV*b*/12*i*. 38.—Silicon fluoride containing calcium fluoride, silicon dioxide, and sulfuric acid is introduced into aqueous fluosilicic acid (preferably in the presence of protective colloids), and the part not required for absorption of the resulting fluosilicic acid is partially or entirely transformed by treatment with equivalent or excessive amounts of calcium carbonate into calcium fluoride and silicic acid. D.A.B.

Production of oxides of tin and antimony. V. HIMMELBAUER. Brit. 502,846, April 5, 1939 (May 6, 1938).

Removing silica from minerals, slags, etc. I. G. FARBENIND. A.-G. Brit. 511,018, Aug. 23, 1939 (April 8, 1938).

White titanium dioxide pigment. ROY DAHLSTROM (National Lead Co.). U. S. 2,170,940, Aug. 29, 1939 (Dec. 24, 1936).

General

Absorption of moisture by ceramic bodies. G. R. RIGBY. *Bull. Brit. Refrac. Research Assn.*, No. 39 (April, 1936); reprinted in *Trans. Brit. Ceram. Soc.*, **38** [7] 411–17 (1939).—Fired clay products, on standing in a humid atmosphere, absorb water even though no liquid water has been in contact with them. R. gives data on the actual rate at which water is absorbed. Specimens exposed to atmospheres of 75% and 35% relative humidities show a continuous increase in weight with increasing time of exposure. The absorption of moisture is most rapid during the first two or three weeks. The moisture absorbed can be attributed to mechanical absorption and to chemical combination, the relative amounts depending on the firing temperature to which the ware has been subjected. R.A.H.

Acceptance and use of respiratory protection by workmen. ANON. *U. S. Dept. Labor, Div. Labor Standards, Bull.*, No. 21 (Part 2), pp. 44–46 (1938); abstracted in *Concrete, Cement Mill Ed.*, **47**, 194–95 (1939); see "National—," *Ceram. Abs.*, **17** [6] 238 (1938). W.D.F.

Annual physical examination. W. E. MISHLER. *Ind. Med.*, **8** [2] 73–75 (1939).—M., chief surgeon of the United States Truck Lines, Inc., of Delaware, calls attention to the high and continually rising costs of accidents in industry but considers that the chief problem confronting industrial managements is the maintenance of employee health. In March, 1935, the United States Truck Lines, comprising sixteen operating companies engaged in various phases of transportation, inaugurated a program of periodic physical examinations for employees, including all new applicants for work. The labor unions objected, but the advantages derived by the workers have won the coöperation of the labor officials. Examinations were given over an area extending from Baltimore to Chicago. These periodic examinations have been instrumental in lowering the costs of operation, reducing labor turnovers, improving public relations, and promoting employee health. The records kept have resulted in several discoveries with a direct bearing on operating efficiency. Most employee injuries were experienced by new men. K.R.

Character and composition of industrial dusts. ANON. *U. S. Dept. Labor, Div. Labor Standards, Bull.*, No. 21 (Part 2), pp. 52–54 (1938); abstracted in *Concrete, Cement Mill Ed.*, **47**, 211 (1939); see "National—," *Ceram. Abs.*, **17** [6] 238 (1938). W.D.F.

Developments in ceramics. A. I. ANDREWS. *Bull. Amer. Ceram. Soc.*, **18** [9] 333–38 (1939).

Dust and fumes in the electron microscope. HERBERT FRIESS AND HEINZ O. MULLER. *Gasmaske*, **11**, 1–9 (1939).—Electrons produced with a potential of 75 kv. are used to make visible those particles which are invisible in an ordinary light microscope. The electron beam can be focused to a point by a magnetic field. The object is supported on a thin collodion film over a hole in a diaphragm. The condenser coil focuses the electrons on the object. An object coil gives a 90× magnification, and a projection coil gives a further magnification of 300× (a total magnification of 27,000×). The image can be viewed on a fluorescent screen or photographed. The penetration power of the electrons is weak; therefore only very thin objects can be penetrated. Particle size distribution curves can be obtained down to 10 mμ. The structure of the particles can be seen and the coagulation followed. Asbestos is still fibrous in the finest particles. Quartz and feldspar have much the same shape as the larger microscopic particles. Metal oxide fumes of lead, arsenic, antimony, tin, titanium, and iron were studied, together with the relative permeability of a filter to these fumes. Twelve photomicrographs are shown. See "Foundation—," *Ceram. Abs.*, **18** [4] 106 (1937). W.D.F.

Introduction to the biochemical study of pneumonoconiosis. R. FABRE AND E. KAHANE. *Arch. Malad. Profess.*, **1** [1] 21–28 (1938).—Much research has been conducted upon the qualitative impregnation of the lung with various dusts and their subsequent passing into the circulation, but little work has been done upon the quantitative amounts of foreign particles found in biological tissues. Results of the application of the authors' method of isolation to the determination of the siliceous load of the lung are presented. The social importance of silicosis and the difficulties of interpreting facts already accumulated caused them to select this dust particle for quantitative study. The procedure involved treatment of the tissue sample with various acids until it underwent total mineralization. The free carbon oxidized, and the insoluble residue (composed of the siliceous substance of the lung) was weighed and given further physical and chemical study. The deposit was gritty and crystalline, showing silica imposed upon the organism rather than residual in it. Siliceous dusts deposited with greater difficulty than those poor in silica, and quartz dusts, contrary to popular view, were slower than others in attacking the pulmonary alveoli. A chart records the percentage amounts (in mg. per 100 g.) of siliceous particles found in the lungs of 33 persons whose deaths were accidental; their ages ranged from less than 1 year up to 80 years. The proportion of silica per 100 parts of these particles is also recorded in the chart. A general but not uniform increase and decrease of siliceous impregnation according to age was observable. The authors conclude that dusts encountered in organs other than the lungs are not derived from digestive processes but are carried away from the lungs by the blood. Besides making progress in the quantitative estimation of siliceous substances in the lung, they present problems for solution hitherto unperceived: (1) the mechanism by which most siliceous particles other than quartz are di-

gested or eliminated; (2) the cause of the relative silica saturation of the lung under normal conditions, although the proportion of siliceous particles taken in decreases with age; and (3) the dissemination of dusts of respiratory origin throughout the organism. The carbon impregnated in the lung, taken in chiefly as soot, is discussed briefly. A chart of quantitative results similar to those recorded for silica proportions is given. Literature on the absorption (or at least the penetration) of fine manganese dust into the pulmonary alveoli is condensed and illustrates the digestion of this finer dust and its subsequent passage into the circulation. K.R.

Mechanical-filter type of respirators. ANON. *U. S. Dept. Labor, Div. Labor Standards, Bull.*, No. 21 (Part 2), pp. 40–42 (1938); abstracted in *Concrete, Cement Mill Ed.*, **47**, 180 (1939); see "National—," *Ceram. Abs.*, **17** [6] 238 (1938). W.D.F.

Particle analysis of industrial dusts. R. MELDAU. *Z. Ver. Deut. Ing., Beiheft Folge*, **1938**, No. 3, pp. 65–75; *Chem. Abs.*, **33**, 5939 (1939).—The recent optical apparatus type of illumination and the preparation of dust slides are discussed. The most satisfactory preparation is obtained by mixing the dust with a plasticizer such as wax, resin, or phenoplast and polishing the solidified mixture. Many photomicrographs and 14 references are given.

Quartz-fusing operations with special reference to the measurement and control of silica fumes. EDWARD C. RILEY AND J. M. DALLAVALLE. *U. S. Pub. Health Repts.*, **54**, 352–69 (March 3, 1939).—Fused quartz is being increasingly used in industry and in the laboratory. It transmits ultraviolet light and has a low coefficient of expansion. Temperatures of 2500° to 3000° are required to blow fused quartz. Above 3200°F it volatilizes rapidly, and the work is difficult. Greater skill is required for fused quartz operations than for glass blowing, and operators have to endure inconvenient personal results at times. Among these are strong, disagreeable odors (caused by the quartz fumes) and the high-temperature effects of radiant energy, ultraviolet and infrared, which cause fatigue and, at times, nausea. Supersonic vibrations produced in the oxyhydrogen jet are thought to increase these symptoms. Operators who fuse quartz, however, work only 2 to 4 hr. per day. This short work period probably accounts for the absence of silicosis among these workers in the U. S. In 1934, among 9 exposed workers in fusing quartz in a German plant, 8 had signs of silicosis. The authors' objectives are (1) to determine the concentration of quartz fumes produced during fusion, (2) to measure the intensity and range of sound frequency produced by flame jets, (3) to design a suitable method for the control of the silica fumes generated, and (4) to estimate the amount of heat produced by the oxyhydrogen flame through its combustion product, steam. The procedure for gaining these objectives is given in detail. Silica-fume concentrations are tabulated. The particles are very fine and readily visible in a Tyndall beam. During all the quartz-fusion tests, characteristic metallic-fume odors prevailed. The loss in weight undergone by the fused quartz at temperatures from 2500° to 3000°F averaged 30 g. per hr., indicating that the vapor pressure of heated quartz is quite high. Quartz temperatures during fusion were determined by an optical pyrometer and ranged from 2700° to 3200°F. Principles involved, both physical and ventilative, for the control of fumes and heat are fully discussed and are embodied in the design of a large hood with asbestos baffles placed inside to intercept some of the radiant heat; it has a generous air exhaust as a practicable solution of the problem for the worker. Apparatus detail measurements are given. Large hoods and large air exhausts are advised. The experiments upon relative sound frequency characteristics of an ordinary large glass-blowing jet and of the oxyhydrogen quartz fusing jet are shown by the curves plotted for each appliance. The presence of quartz in the jet changed the sound somewhat, but at all frequencies the glass-blowing jet gave greater intensity effects than the other jet, particularly in the range slightly above audible, about 17 to 20 kc. Physiological effects from audible and supersonic vibrations appeared much less likely from the quartz-fusing operations than from those of ordinary glass blowing. Radiation from quartz at the temperatures cited is very intense in the infrared and visible ranges; although it drops rapidly in the shorter wave lengths, there may be some ultraviolet. Goggles for this kind of work should be good filters for infrared as well as for visible light; the small amount of ultraviolet emitted will generally be removed by ordinary goggles. Glare is the most important effect to be avoided. K.R.

Second international conference on silicosis, Geneva. ANON. *Foundry Trade Jour.*, **59** [1166] 465 (1938).—Initial examination of workers entering industries exposed to silica dust is justified as a routine procedure if only to detect tuberculosis and thereby protect the worker from added risk. Early removal from the dusty occupation of a case of simple silicosis may slow down the process and lead to a substantial degree of arrest. It is important to measure the intensity of exposure to dust concentration and the composition and size-frequency distribution of the dust. The procedures applicable to dust suppression are considered. Dust-protection masks should have low resistance to breathing and should provide a high degree of protection against particles of dust found in industry. They should fit the face and be reasonably comfortable to wear. Disability can best be determined by a complete examination of the applicant, including X-ray examination. The conference was not cognizant of any specific therapeutic measure for the treatment of silicosis or any method of stimulating the elimination of silica from the lungs. H.E.S.

Silicosis dangers in frit making. ANON. *Foundry Trade Jour.*, **59** [1146] 92 (1938).—The danger to workers engaged in the preparation of raw materials for frits is chiefly centered in the use of finely ground quartz. Alumina powder has been substituted for flint in the biscuiting of china with considerable success. A fine quality sand from Fontainebleau which is virtually free from iron has been substituted for quartz in frits. These methods of substituting noninjurious materials for dangerous materials are reducing silicosis risks. H.E.S.

World supplies of bauxite. ALUMINUM INFORMATION BUREAU. *Foundry Trade Jour.*, **59** [1160] 344 (1938).—Almost all of the world's supply of bauxite is produced in the following countries: France (688,200 metric tons in 1937), Hungary (510,000), the U. S. (425,000), Dutch Guiana (392,300), British Guiana (305,600), Italy (370,400), Jugoslavia (357,800), the U.S.S.R. (230,000), Dutch East Indies (122,300), Germany (18,000), and other countries (34,800). The world total for 1937 was 3,653,400 metric tons. H.E.S.

BOOKS AND SEPARATE PUBLICATIONS

Elementary Thermodynamics. V. M. FAIRES. Macmillan Co., New York, 1938. 225 pp. Price $2.60. Reviewed in *Power*, **82** [12] 703 (1938). F.G.H.

High-Frequency Ceramic Products (Hochfrequenzkeramik). E. ALBERS-SCHÖNBERG with the collaboration of H. HANDREK, W. SOYCK, AND G. UNGEWISS. Vol. 2 of Industrial Ceramics (Industrielle Keramik), edited by W. Steger, Berlin. Theodor Steinkopff, Dresden, 1939. xi + 171 pp., 97 illustrations. Price 11 Rm, bound 12 Rm.—This first comprehensive work on the newest field of technical fine ceramics contains a systematic critical compilation of all publications. It concerns the ceramist, chemist, electrotechnician, physicist, and builder. A detailed treatment is given of molding processes together with the latest results of research on plasticity and the combination with water of ceramic raw materials. Other subjects discussed are the transformation of the green mix into the final insulating material during firing; new processes for combining ceramic parts with metal and glass; the physics of ceramic insulating materials, with a summary of the mechanical, thermal, and electrical properties; uses of materials in high-frequency technique; and ceramic condensers. The new materials, titanium dioxide and magnesium titanate base substances, are, for the first time, systematically treated. M.V.C.

Pneumonokonioses (Silicosis) Literature and Laws: III. GEORGE G. DAVIS, ELLA M. SALMONSEN, AND JOSEPH L. EARLYWINE. Chicago Medical Press, Chicago, 1937. 1033 pp. Price $8.50. Reviewed in *Foundry*, **66** [6] 74 (1938).—Part I includes abstracts of articles on silicosis published during 1935 and 1936 in the U. S. and foreign countries. Part II gives the occupational disease laws pertaining to pneumonokonioses in force in the U. S. and in several foreign countries. Subject and author indexes and a bibliography are included. See *Ceram. Abs.*, **14** [11] 297 (1935). F.G.H.

Research for Ceramic Industries. ANON. *Battelle Memorial Inst. Booklet*, 16 pp.; reviewed in *Foundry*, **66** [9] 94 (1938).—The work of the Institute in research on abrasive, cement, glass, pottery, and refractory products is illustrated. F.G.H.

PATENTS

Glaze. J. D. MORGAN (Power Patents Co.). U. S. 2,170,387, Aug. 22, 1939 (May 25, 1937).—A high temperature resistant glaze is formed by thoroughly mixing and reacting a mixture of about 90 to 50 parts by weight of finely ground zircon, about 10 to 50 parts by weight of phosphoric acid, and a small proportion of finely ground ferrosilicon.

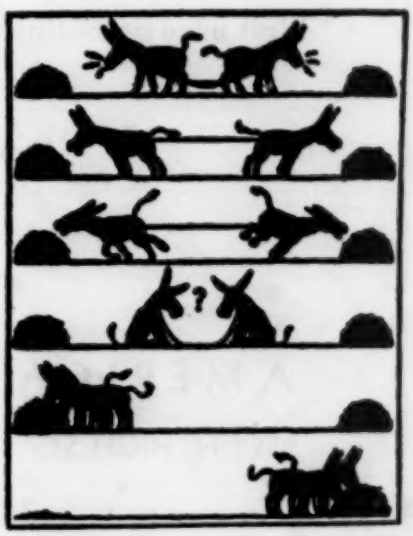
Making clay products. F. B. HOBART (Battelle Memorial Inst.). U. S. 2,171,290, Aug. 29, 1939 (Jan. 14, 1937).—A method of making a ceramic product comprises making a suspension of ceramic material in water, wherein the ceramic material has been selected because of its ability to effect gelation of a soluble silicate to be subsequently introduced and wherein the suspension has a p_H value suitable for attainment of gelation at a desired time, and adding the soluble silicate in powdered form to bring about gelation and consequent conversion of the suspension from a liquid to a solid phase.

Union of metallic parts with ceramic materials. OTTOKAR STORCH AND OSKAR NAUMANN (Porzellanfabrik Kahla). Ger. 674,734, March 30, 1939 (Jan. 25, 1937); VI/80*b*. 23.10.—The union of metallic parts with insulating materials of inorganic substances such as ceramic material is brought about by causing the metallic part to penetrate the insulating material. The metallic part is fixed into the ceramic material by means of heat and pressure without changing the shape of the metallic part which consists of metal that can be shaped in any manner. An easily formable metal part is inserted between the main metallic part and the ceramic material, and, by passing an electric current through the metals, heat is produced for the softening of the metal insert. D.A.B.

All You Can Do by and through This Society, You Do for Yourself

IT IS ONLY BY COMMUNICATION WITH OTHERS THAT KNOWLEDGE IS ACQUIRED

Forward-going aggressive ceramists succeed only by continually studying —not narrowly, but broadly—the current problems in all ceramic fields.



IMPORTANT TO OUR MEMBERS

MEMBERSHIP SOLICITATION:

War in Europe and the East will prevent several of our personal and corporation members abroad from paying their dues which now aggregate $3300.00 per year. Many of our foreign subscribers, now totaling 361, may be unable to renew.

To carry on as during 1939, this Society must receive an increase in membership subscription from American ceramists of $7541.90.

Personal Membership Dues	**$12.50**
Minimum Corporation Subscription	**$25.00**

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To meet the expenses of publications the Society is compelled to offer sales message space in The Bulletin. The members should present this opportunity to those from whom they purchase materials and equipment.

	Number of Insertions			
	1 month	*3 months*	*6 months*	*12 months*
Full page	**$66.00**	**$60.00**	**$52.00**	**$44.00**
Half page	**36.00**	**33.00**	**30.00**	**26.00**
Quarter page	**20.00**	**18.00**	**16.50**	**15.00**
Eighth page	**10.75**	**9.90**	**9.00**	**8.25**

Classified advertisements: 35 words for $1.10 per insertion

Cover positions: list plus 25%

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AMERICAN CERAMIC SOCIETY

2525 N. HIGH ST. COLUMBUS, OHIO

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